INCOMPLETE MARKETS AND THE ENDOGENEITY OF CENTRAL BANKING

by

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Abstract

Incomplete Markets and the Endogeneity of Central Banking

In a model with incomplete markets, and agents privately producing a circulating media of exchange to coordinate trade, it is shown that closing another market can be Pareto-improving. Producing private money is costly because contracts with the money issuers must be enforced, creating agency costs. By closing the market for trading the circulating media, agents endogenously create an information asymmetry which can result in banking panics. The information asymmetry is desirable, however, because it creates externalities which force banks to cooperate for mutual regulation and insurance for their monies, thus reducing agency costs. The self-enforcing cooperative coalition of banks replaces the market in enforcing the private money contracts. Agents relying on this unobservable enforcement are said to have "confidence" in the banking system.

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I. Introduction

That markets are information revealing institutions is a well-known and oft-studied proposition. Information is revealed because of noncooperative interaction between market participants. Usually, the existence of such markets is thought to be desirable, that is, welfare is improved. In this essay, a counterexample to this general view will be studied. Here, by closing a market, and hence, eliminating the information revealed by the market, agents will be induced to behave cooperatively and everyone will be better off.

The result occurs in the context of studying the banking industry. A literature has recently grown around the question of whether banks are, in some way, "special" or unique, hence justifying government regulation. (E.g., Diamond and Dybvig (1983).) This literature focuses on the existence of banking panics; it proceeds by assuming that information asymmetries exist, and then generates the existence of banks as an incentive-compatible solution to the contracting problems arising under incomplete information. Then it is shown that banking panics are an inherent feature of the resulting banking contract. Regulation may then be required because of the market failure.

Theoretically, the distinguishing feature of the present work is that the information asymmetry is not assumed, but arises endogenously. As a consequence, the results here are quite different than the received literature. An important problem with this literature is that not all banking systems have experienced panics. The outstanding counterexample is the early Scottish system (see White (1984)). Yet, theoretically, models of banks which can produce panics, produce them inherently.

Such analysis creates a dichotomy between "markets," in which there may the model and outside the private economy. In contrast, here agents prefer to arrange institutions so that a "market failure" occurs. The information asymmetry which is generated by the agents, causes externalities which produce the preferred form of industrial organization, namely, a cooperative coalition of banks arises to replace the market.

The cooperative coalition of banks is a quasi-governmental institution which, in various forms, is common to the history of banking in most countries. These industry associations regulated their members, often in precisely the same ways that governments regulate banks today. (See Cannon (1910), Gorton (1985B), Gorton and Mullineaux (1986), Timberlake (1984), White (1984).) Thus, we will show how cooperative institutions, which behave like the government, are not opposed to "markets." The origin of government regulation turns out to be private "regulation."

The model studied is one in which there is an absence of trust, as in Gale (1978). Gale shows that if agents cannot rely on each other's promises to deliver goods, then government fiat money can coordinate trade by accounting for agents' net positions, enforcing budget constraints. Gorton (1987) studied whether, instead of exogenous government money, agents can trust other agents to privately produce money which replaces Arrow-Debreu-type "trust" in the exchange process. Will private money issuers maintain the value of their monies when there are incentives to behave in a dynamically inconsistent manner? Gorton shows that the commitment problem can be privately solved by forming banks. Banks arise as issuers of private money because they can arrange a liability structure which eliminates the incentive to overissue money (i.e., banks can precommit to be "trustworthy").

A bank commits to not overissue by using equity as collateral which the bank must forfeit if it overissues. Holders of a bank's money have an option to redeem the money on demand at the bank, so they can credibly threaten the bank's equity. The credibility of the threat, and, indeed, the feasibility of the banking contract, depends on a market price system which reveals any inflation. In other words, agents must be able to observe an informative (relative) market price of each money.

The present study assumes the optimality of the basic contract derived in Gorton (1987). Details about the contract are reviewed in Section II. The question asked here, in Section III, is whether it is desirable to close the market where private monies are traded. That is, would a system in which private monies always traded at uniform relative prices be Pareto-superior. This question arises because the bank contract is costly if the required amount of equity the banking system must hold is a binding constraint on the economy. Another arrangement may be able to reduce or eliminate these agency costs.

When relative private money prices are uniform, and hence, noninformative, then not only are agents incapable of credibly threatening banks, but they lose important information about underlying bank portfolios. Now, unlike the set-up with full information revealed by market prices, households sometimes mistakenly opt to redeem money at banks, misallocating resources. Thus, without market information the bank contract is both infeasible (because the threat required to make the contract viable is gone) and undesirable (because of mistakes in resource allocation).

It is shown in Section IV that to prevent the mistakes of incorrectly redeeming in the wrong states, banks will cooperate to offer insurance to households so that the suboptimal liquidation of investments will not occur.

ratio and interest rate ceilings. These regulations make the bank contract both feasible and desirable because agency costs are reduced.

Section V concludes by relating these results to some of the existing literature mentioned above.

II. The Model Economy with Circulating Bank Debt

The model economy to be analyzed has four time periods (t = 0, 1, 2, 3). At t = 0, the planning period, households receive endowments and choose savings and consumption strategies. Households trade at the start of periods one and two and then consume during the respective periods. During the final period (t = 3) there is no trade, but all claims are extinguished, leaving households with their realized, end-of-world, wealth which is consumed.

Imagine colonies of households at different locations, say around a circle. Goods come in many colors, but households at location i receive only a single-colored endowment of goods (Y_{0i}) and a quantity of gold (G_0). Households at location i all receive the same color endowment. Colors vary across locations, but all households receive gold, in addition. Household preferences during periods one and two are for a bundle of goods of different colors (except gold), in fixed proportions, as in Lucas (1980). In the final period, households are indifferent about color.

Households have a storage technology only capable of storing goods of the color of their endowment. Households also have risky, long-term, investment opportunities. A unit of any colored good may be invested at t = 0 and is expected to earn $(1 + r)\theta^e$ of any desired color at t = 3, the final period, where θ is a random variable described below. Finally, each household is endowed with a money printing machine which can print a distinguishable, The investment portfolios face random shocks, with a common or aggregate component, λ_1, and an idiosyncratic component, ε_{1j}, both of which exhibit persistence according to:

$$\theta_{2j} - \bar{\theta}_2 = \xi(\varepsilon_{1j} - \bar{\varepsilon}_1) + \delta(\lambda_1 - \bar{\lambda}_1) + \mu \qquad \forall j \tag{1}$$

where $\xi, \delta > 0$, $E(\lambda_1) = \bar{\lambda}_1$, $E(\varepsilon_{1j}) = \bar{\varepsilon}_1$, $E(\theta_{2j}) = \bar{\theta}_2$, and μ is white noise with density function $Z(\mu)$. To ease notation, and without loss of generality, assume $\xi = \delta$, so (1) can be written: $\theta_{2j} - \bar{\theta}_2 = \xi\left[\varepsilon_{1j} + \lambda_1 - (\bar{\varepsilon}_1 + \bar{\lambda}_1)\right] + \mu$. Then define the <u>state of bank j's portfolio</u> at the end of period one to be: $\theta_{1j} \equiv \varepsilon_{1j} + \lambda_1$.

The investment shock process has two important features. First, because of the persistence, if the state of a portfolio after the first period is above (or below) its mean it will likely be even further above (or below) at the end of the world. Second, because of the different shocks affecting the portfolio, there is the possibility that households can be less than fully informed about the state of portfolios. However, we will always assume that all households know λ_1, the common shock to portfolios.

Each household is a buyer/seller pair. Buyer/seller pairs cannot communicate while trading, but both can observe market prices. When markets open at the beginnings of period one and two, household buyers go to the market to buy goods with money. Money consists of privately issued circulating debt, described below, or gold. At the same time that buyers go to the market to shop, sellers go to the market to sell goods (from the households' endowments), receiving money in exchange. When markets close, after the first period, buyers and sellers return home and consume.

portfolio of monies which the sellers received during the first market. Meanwhile, in the second market, sellers again sell goods (from endowments), receiving money which will be carried over into the final period and redeemed at issuing banks.

In the above scenario, trade may be implemented with privately issued circulating claims. However, households are not assumed to be pathologically honest, so without a viable contract, households cannot be prevented from overissuing such claims, i.e., reneging on any initial promise not to do so. Gorton (1987) has addressed this issue and has shown that a contract with the private money issuer can prevent the dynamically inconsistent behavior of overissuing private claims. In this study the basic form of that contract is assumed, so it is summarized here as:

DEFINITION 1: A bank is a household offering a contract where:

(i) the circulating claims are debt claims; (ii) the circulating debt has an option for redemption into gold, at par, on demand (i.e., at the end of period two); (iii) there is a minimum equity-debt ratio required.

Gorton (1987) shows that this contract is sufficient for preventing overissuing.[1] The intuition for this is as follows. Suppose the bank begins to issue more notes after initially contracting with household depositors. Households will observe the relative (to gold) price of that bank's money decline until it is profitable to exercise the option, redeeming the money after period one. If there is a technological limit on the amount of overissuing, then depositors can choose an equity-debt ratio initially so that overissuance is never profitable because the equity will be lost when promise not to inflate. In equilibrium the equity cannot be traded because the initial owner still controls the printing press. Consequently, if another party bought it, nothing would prevent overissuing, making the equity worthless (see Gorton (1987)).

The circulating claims issued by bank i promise ex ante to pay the two period rate of return, $1 + r_{Ni}$, at the end of the world. Let P_{ti} be the gold/i-money exchange rate during period t, and P_t be the gold/goods exchange rate during period t. M_{ti} is the outstanding nominal stock of the i^{th} bank's money (i-money) during period t. Equity in bank i is Q_i. Since equity is the residual claimant (by Definition 1) and the outcome of the investment process is uncertain, there is the possibility that banks pay out less than what was promised in the final period. At the end of the world bank i will redeem notes at $P_{3i}(1 + r_{Ni})$ where:

$$P_{3i} = \begin{cases} 1 & \text{if } \theta^*_{2i} \le \theta_{2i} \le \tilde{\theta}_2 \\ \dfrac{(1 + r)\theta_{2i}[M_{1i} + Q_i]}{(1 + r_{Ni})M_{3i}} & \text{if } \underset{\sim}{\theta}_2 \le \theta_{2i} \le \theta^*_{2i} \end{cases} \tag{2}$$

θ^*_{2i} is the lowest value of the shock which allows bank i to pay off its note holders at par, i.e., $\theta^*_{2i} = \dfrac{(1 + r_{Ni})M_{3i}}{(1 + r)[M_{1i} + Q_i]}$. Also, if redemption is demanded early, there is the possibility, depending on the state of the bank's portfolio, that liability holders suffer a capital loss. At the end of the first period, then, the value of a dollar of the i^{th} bank's notes is given by:

$$P_{2i} = \begin{cases} 1 & \text{if } \theta^*_{1i} \le \theta_{1i} \le \tilde{\theta}_1 \\ \dfrac{\theta_{1i}[M_{1i} + Q_i]}{M_{2i}} & \text{if } \underset{\sim}{\theta}_1 \le \theta_{1i} < \theta^*_{1i} \end{cases} \tag{3}$$

where θ^*_{1i} is the lowest value of the shock which allows the bank to redeem its notes at par, i.e., $\theta^*_{1i} = \frac{M_{2i}}{M_{1i} + Q}$.

Let C_1 and C_2 be consumption during the first and second periods. S_1 and S_2 are inventories of endowments to be stored and then sold by the household seller during the respective markets. I_Y is the amount of the colored good invested; I_G is the amount of gold invested. Define the total: $I \equiv I_Y + I_G$. W is end-of-world wealth. The representative household, say the j^{th}, will choose investments of I_Y, I_G, $Q_i(\forall i)$, and money, M_{1j}. These items will all earn returns in period three. Also, amounts to store for sale to other agents need to be chosen (i.e., S_1 and S_2). The problem is to choose these amounts to:

$$\text{MAX:} \quad E_0\{U(C_1) + \beta U(C_2) + \beta^2 \Lambda(W)\} \tag{I}$$

subject to:

(i) $Y_0 = M_{1j} + S_1 + S_2 + I_Y + \Sigma Q_i$ (Budget Constraint for Colored Good)

(ii) $G_0 = G_1 + I_G$ (Budget Constraint for Gold)

(iii) $C_1 \leq \frac{G_1 + M_{1j}}{P_1}$ (Buyer; first market)

(iv) $\frac{G_2 + \sum_i M_{2i}}{P_1} = S_1$ (Seller; first market)

(v) $C_2 \leq \frac{G_2 + \sum_i M_{2i}P_{2i} + (C_1 - S_1)}{P_2}$ (Buyer; second market)

(vi) $\frac{G_3 + \sum_i M_{3i}P_{2i}}{P_2} = S_2$ (Seller; second market)

(vii) $W = G_3 + \sum_i M_{3i}P_{3i}(1+r_{Ni}) + (1+r)\theta_{2j}I + \sum_i (1+r_{Qj})\, Q_j + (C_2 - S_2)$

(Final Wealth)

(viii) $M_{1j} < \Gamma_N Q_j$ (Incentive Compatibility)

The representative household's Problem, (I), corresponds to the trading scenario outlined above. Constraints (iii) and (v) are the cash-in-advance constraints which are required due to the lack of trust. Constraints (iv) and (vi) express the household seller's sales of endowment in terms of the portfolio received. Assume that $U' > 0$, $U'' < 0$, and $0 < \beta < 1$.

Before solving Problem (I) we want to distinguish between two types of industrial organization which will be studied in the next section. The contract embedded in Problem (I) corresponds to an organizational setting in which the household itself will "clear" the circulating claims by redeeming them at various banks. Notice that the final wealth constraint, (vii), of Problem (I) shows the household ending up with claims on banks at (possibly) all other locations. Each household must, thus, assume the risk associated with the claims of (possibly) every bank in the economy. Without explicit modelling we will imagine a division of labor in which households act as note brokers, specializing in the production of information about banks. Assume, in particular, that household j costlessly learns the state of bank portfolios of banks at location j+1, i.e., ε_{1j+1} is learned (λ_1 is common knowledge). Call this arrangement a bank note contract.

An alternative arrangement is an industrial organization in which claims clear within the banking system. After each individual transaction, claims return to the banks and the banks themselves act on the households' behalf to market, household i's buyer "writes a check" to household k's seller. Household k's seller takes the check to his bank. k's bank takes the check to bank i (household i's bank). Bank k credits household h's account after bank i debits its account and transfers the credit to bank k. During period three household j has a claim on a single bank, bank j, which is redeemed. With checks constraints (iv), (v), (vi), and (vii) will be modified to reflect the fact that households have a single checking account with a bank at their location. Thus, instead of a portfolio of many monies, households will only hold a single money.

Though this internal clearing arrangement is not restricted to checks, we will call this system the demand deposit contract. Its distinguishing feature is the assumption that note brokers do not operate, and consequently, bank states are not assumed to be known by households under the demand deposit contract. Under the demand deposit system, banks know each other's states, and households are uninformed. Under the note contract, household j learns about banks at j+1. (Recall that household j *is* bank j.)

The difference between the two contracts will also modify constraint (viii) of problem (I) which imposes the minimum equity-debt ratio associated with notes. The number Γ_N is derived in Gorton (1987). Note that if this constraint is binding on the representative household, then all investment must be through the banking system, i.e., I = 0. Assume constraint (viii) binds. The focus subsequently is on deriving a constraint on the equity-debt ratio under the demand deposit contract. If the minimum equity-debt ratio under the demand deposit contract is lower, then the constraint may not bind, i.e., households may be willing to save that amount until period three anyway.

III. Bank Notes and Demand Deposits

Problem (I) is a dynamic programming problem, so we begin with solving for the second period equilibrium. Subsequent analysis is facilitated by assuming that households are risk neutral with respect to end-of-world wealth, i.e., $\Lambda(w) = a + bW$, a, b > 0. This assumption is convenient because households will, as a result, choose corner solutions, making the choice, subsequently, between the different types of contracts, distinct.

At the end of period one, the household buyer must choose an amount to consume, subject to financing the purchases with the portfolios of monies on hand. The household seller has an inventory of endowment goods to sell and, in the process of exchange through the money market, chooses a portfolio of monies to be carried over into the final period. Recall, also, that the incentive compatibility constraint in problem (I), (viii) is imposed to prevent overissuing. The j^{th} household buyer/seller pair determines first order (Kuhn-Tucker) conditions for i-money and gold:

$$\frac{U'_{c2}}{\beta b} - P_2 \frac{[P^e_{3i}(1 + r_{Ni}) - \lambda_N]}{P_{2i}} \geq 0 \qquad \forall i \ (= \text{ if } M_{3i} > 0) \tag{4}$$

$$\frac{U'_{c2}}{\beta b} - P_2 \geq 0 \qquad (= \text{ if } G_3 > 0) \ . \tag{5}$$

λ_N is the Lagrange multiplier on the constraint (viii). Above we assumed that this constraint was binding.

Recall that at the start of period two, all households have identical portfolios. And upon completion of trading in the goods market, all sellers go to the money market with their portfolios. The first order conditions (4) and (5) will not all hold simultaneously. Notes will be chosen if the of particular importance for what follows. The following proposition characterizes the equilibrium.

PROPOSITION 1: Note prices are informative. In particular, for each bank, j, there exists a bank-specific level of the aggregate shock, λ^*_{1j}, such that for all $\lambda_1 < \lambda^*_{1j}$, households will exercise the (put) option on j-notes, redeeming them for gold and ending the long-term investments.

Proof: From equation (4), the exchange rate between i-notes and ℓ-notes is:

$$e_{\ell i} \equiv \frac{P_{2i}}{P_{2\ell}} = \frac{P^e_{3\ell}(1 + r_{N\ell}) - \lambda_N}{P^e_{3i}(1 + r_{Ni}) - \lambda_N}, \qquad \forall i,\ell \tag{6}$$

Household i - 1 knows ε_{1i}, by assumption, and since λ_1 is common knowledge, knows θ_{1i}. Hence, household i - 1 knows the true P_{2i}. Suppose, however, that household i - 1 attempted to charge $\hat{P}_{2i} < P_{2i}$, i.e., tried to buy i-notes for less than they are worth. But, since the market is competitive, exchange rates must satisfy (6), i.e., $P_{2i}/\hat{P}_{2i}$ must equal one. Since λ_1 is known, ε_{1j} is revealed by P_{2j}.

From the first order conditions (4) and (5), household j exercises the option to redeem j-notes for gold if:

$$\frac{P^e_{3j}(1 + r_{Nj}) - \lambda_N}{P_{2j}} < 1 \tag{7}$$

because, if (7) holds, then the rate of return on gold is higher than the

$$P^e_{3j} = \int_{\mu^*_j}^{\tilde{\mu}} Z(\mu)d\mu + \int_{\underset{\sim}{\mu}}^{\mu^*_j} \left[\frac{(1 + r)(\mu_{1j} + Q_j)}{(1 + r_{N1})\mu_{1j}}\right]\{\bar{\theta}_2 + \xi[\varepsilon_{1j} + \lambda_1 - (\bar{\varepsilon}_1 + \bar{\lambda}_1)] + \mu\}Z(\mu)d\mu \; . \tag{8}$$

Substituting (8) into (7) and solving for λ_1 as a function of the realized ε_{1j} defines λ^*_{1j} as the lowest value of λ_1 for which (7) holds. ‖

In other words, households will switch from j-notes to gold if, knowing λ_1 and ε_{1j}, the expected rate of return on the notes is dominated by gold.

Equilibrium requires $C_2 = S_2$, which determines the price level, P_2. Note that, in equilibrium, $G_2 = G_3$ if gold is chosen, or $M_{2i} = M_{3i}$, if i-notes are chosen. Imposing the second period equilibrium on problem (I), the first order conditions for household j at the beginning of the world for the joint goods market decision, equity in bank j, and investments, can be determined. (These are omitted here.)

Demand Deposits

Now consider demand deposits. Assume that households only hold checking accounts at a single bank at their own location. Notationally, let D_{tj} be household j's deposit holdings in period t. r_{dj} is the promised two period rate of return on deposits. Explicit presentation of the representative household's problem is omitted. As before, a buyer/seller pair determine first order (Kuhn-Tucker) conditions for deposits and gold:

$$\frac{U'_{c2}}{\beta b} - \frac{P_2[P^e_{d3j}(1 + r_{dj}) - \lambda_D]}{P^e_{d2j}} \geq 0 \qquad (= \text{if } D_{2j} > 0) \tag{9}$$

Households, as before, choose a corner solution, holding either deposits or gold. λ_D is the Lagrange multiplier for deposits, associated with a minimum equity-debt ratio. This will be determined in the next section.

Since by assumption note brokers do not learn bank states under the deposit contract, we have that:

PROPOSITION 2: In equilibrium, no bank states are revealed by note prices.

In particular, there exists a level of the aggregate shock, λ_1^{**}, not bank-specific such that for $\lambda_1 < \lambda_1^{**}$, household j, and all other households, exercise the option on deposits, redeeming them for gold and ending the long-term investments.

Proof: See Appendix.

Remark: As before the household compares expected rates of return, according to (9) and (10) to decide whether to switch from deposits to gold. Since, by assumption, ε_{1j}, $\forall j$, is not known, the decision cannot depend on this. Hence, the critical value, λ_1^{**}, is not dependent on ε_{ij}.

Note that households switch from deposits to gold under different conditions than when they held notes. In particular, without knowing ε_{1j}, households now base their decision only on λ_1. Figure 1 portrays the two decision rules.[2]

Consider the choice between the bank note contract and the deposit contract. Suppose that at the beginning of the world both contracts were available. Households know their decision rules for the second period. If notes were chosen initially, then, in period two, households switch to gold

DEFINITION 2: The value of the option to withdraw gold in exchange for notes or deposits is the difference in utility between withdrawing and not withdrawing when the strategy of withdrawing is optimal according to Propositions 3 and 4, respectively. Denote the marginal value of the option, i.e., the derivative with respect to notes or deposits, respectively, as MVO_N and MVO_d. (See Appendix, equations (A3), (A5).)

Using the decision rules described by Propositions 1 and 2, and the definition of the value of the option, the beginning of the world problem can be solved. In that solution, households will choose either note or deposits.

PROPOSITION 3: At t = 0 household j chooses the deposit contract if:

$$E_0[MVO_d] - E_0[MVO_N] - \frac{[\lambda_D - \lambda_N]}{\beta^2 b} > 0 \qquad (11)$$

where "E_0" indicates expected value at t = 0.

Proof: See Appendix.

Proposition 3 compares the expected marginal values of the options and the required agency costs associated with each contract. To be more precise about this comparison:

PROPOSITION 4: Suppose households hold the same amounts of circulating bank debt, and equity, under each contract, and that the promised rate of return on bank debt is the same under each contract. Then, if agency costs were zero, i.e., $\lambda_N = \lambda_D = 0$, deposits would never be chosen because:

Remark: The requirement that $\lambda_N = \lambda_D = 0$ is a sufficient, but not necessary condition. Positive agency costs make the comparison tedious without changing the result.

Households expect to make mistakes under the demand deposit contract, withdrawing currency when they would not under the note contract, and not withdrawing currency when they would under the note contract. See Figure 1. Under the note contract, resources are reallocated by exercising the option based on bank-specific information. Specific banks may be closed while others are not. However, under the deposit contract, there is no way to distinguish one bank from another: if one bank is closed, all are closed. Consequently, households would choose the informative note contract. The mistakes under the deposit contract occur because information is incomplete. Gorton (1985A) has a similar result.

DEFINITION 3: A banking panic is said to occur if households exercise the option to withdraw deposits or cash in notes at all banks.

A banking panic involves all banks in the banking system. With a large number of banks, a banking system organized around the note contract can never have a panic because all banks will never be insolvent.

The results of this section are summarized as:

Theorem 1: If there are many banks, then a banking panic can only occur under the demand deposit contract.

IV. Clearinghouse Coalitions

case of notes, the price of bank j's notes in the money market will reveal overissuing, making the threat of redemption credible. Demand deposits can also be "overissued" by the bank writing checks without depositing resources. With the deposit contract there is no possibility of households detecting overissuing because prices are not informative. Thus, in addition to being undesirable, the demand deposit contract appears not to be feasible. In this section we show that a cooperative organization of banks can make the deposit contract feasible and desirable <u>precisely because the contract creates an information asymmetry</u>.

<u>DEFINITION 4</u>: A <u>Clearing House Coalition</u> (CHC) is a unanimous agreement among banks at $t = 0$ which: (i) specifies a minimum equity-debt ratio which each bank must satisfy; (ii) requires $1 + r_{di} \leq 1 + r_d$, $\forall i$; and (iii) specifies an action for the coalition to take in the event of a banking panic at the end of period one.

The process of clearing is assumed to reveal information. In particular, assume that the CHC costlessly learns ε_{1j} at the end of period one, and can detect overissuing of member bank liabilities.

The problem with panics is as follows. During a banking panic, depositors seek to end the long-term investment process because the perceived risk of demand deposits has changed conditional on the observed, non-bank-specific, information, λ_1. When a panic occurs, some banks have a positive net worth and some do not, but depositors do not know which banks are which. The CHC knows which banks are solvent and must credibly signal depositors.

make this action possible. There are two types of actions to be considered: banks can pool or separate.

DEFINITION 5: A Pooling CHC is a sharing, or coinsurance, rule triggered in the event of panic. Under this rule, in the event of panic, the CHC: (i) suspends the depositors' option to convert bank liabilities into currency; and (ii) pools all member bank assets in order to assume all the debts of members, i.e., losses are shared, but ownership of the assets reverts to the original banks once all debt is paid off, i.e., profits are not shared.

DEFINITION 6: In the event of panic, a Separating CHC publicly identifies the insolvent member(s) by announcement.

The Stability of Clearing House Coalitions

A separating CHC attempts to replicate the note market by revealing the insolvent banks.[3] The long-term investments of the insolvent banks, and not the other banks, would be liquidated. With the pooling CHC, no long-term investments are ended, though some might be ended under full information. To consider the stability of the coalition types, we make the following definition.

DEFINITION 7: A breaking coalition is a subset of the total number of banks which at $t = 0$ refuses to join the CHC, or a subset of the CHC membership which, in the event of a panic at the end of the first period, acts to thwart the CHC act of pooling or separating.

<u>Proof</u>: The proof consists of showing that a breaking coalition can always exist no matter how many banks are in the CHC, and no matter what the equity-debt ratio. Suppose there is a panic. Solvent banks prefer not to liquidate their investments. But, since households are risk neutral with respect to final consumption, insolvent banks also prefer not to liquidate their investments because there is a positive probability of recovering if they are allowed to continue. Any action that the solvent member banks of the CHC take to publicly identify the insolvent members can be thwarted by the insolvent members unless households can be assured <u>ex ante</u> that a majority of the identical banks will always be solvent. Let n be the total number of banks in the CHC, and m the number of insolvent members. Then a stable, separating, CHC requires $\text{Prob}[m > (n/2) + 1] = 0$, i.e., a majority of members is <u>always</u> solvent. But this can never be satisfied because all banks face an idiosyncratic shock which can bankrupt them at the end of period one. ||

To examine the stability of the pooling CHC, consider the following pooling arrangement. When a panic occurs, the CHC announces the suspension of convertibility of demand deposits into currency, pools all members assets into a single portfolio, and exchanges household claims on this portfolio for <u>all</u> household demand deposits. Call these claims "loan certificates" (LC), following historical usage.[4] Upon issue, the value of a loan certificate dollar is:

$$P_{2L} = \begin{cases} 1 & \text{if } \theta^*_{1L} \le \theta_{12} \le \tilde{\theta}_1 \\ \dfrac{\sum_i \theta_{1i}[D_i + Q_i]}{\sum_i D_i} & \text{if } \underset{\sim}{\theta}_1 \le \theta_{12} < \theta^*_{1L} \end{cases} \qquad (13)$$

All banks are identical, so $D_i = D$, $\forall i$, $Q_i = Q$, $\forall i$. So θ^*_{1L} is given by:
$\theta^*_{1L} \equiv \left(\frac{1}{n}\right) \sum_{i=1}^{n} \theta^*_{1i} = \frac{D}{(D + Q)}$, i.e., θ^*_{1L} is the lowest average bank state at which the CHC could redeem the loan certificates at par.

At the end of the world, a dollar of loan certificates is a claim of $1 + r_{dj}$ on the CHC. Recall that after period one, θ_{1i} has been realized. Define: $\mu^*_1 = \theta^*_{2i} - \bar{\theta}_{2i} + \xi(\theta_{1i} - \bar{\theta}_{1i})$. Then, the gold price of a loan certificate dollar at the end of the world is:

$$P_{3L} = \begin{cases} 1 & \text{if } \mu^*_L \le \mu_L \le \tilde{\mu}_L \\ \dfrac{\sum_i (1 + r)\theta_{2i}[D + Q]}{\sum_i (1 + r_{di})D} & \text{if } \underset{\sim}{\mu}_L \le \mu_L \le \mu^*_L \end{cases} \tag{14}$$

where $\mu^*_L \equiv \sum_i \mu^*_i$, and $\mu_L \equiv \sum_i \mu_i$.

Consider the situation of an individual bank after period one. At the end of the first period, the value of an equity share in bank i is:

$$P_{Qi} = \begin{cases} \dfrac{\theta_{1i}[D + Q] - D}{Q} & \text{if } \theta^*_{1i} \le \theta_1 \le \tilde{\theta}_1 \\ 0 & \text{if } \underset{\sim}{\theta}_1 \le \theta_{1i} < \theta^*_{1i} \end{cases} \tag{15}$$

If $P_{Qi} > 0$, then the bank is solvent; otherwise it is insolvent. If depositors do not withdraw their deposits at the end of period one, then, at the end of period two, the value of an equity share in bank i is:

$$P_{Q3i} = \begin{cases} \dfrac{(1 + r)\theta_{2i}[D + Q] - (1 + r_{di})D}{Q} & \text{if } \mu^*_i \le \mu_i \le \tilde{\mu} \\ 0 & \text{if } \underset{\sim}{\mu} \le \mu_i < \mu^*_i \end{cases} \tag{16}$$

where, as before, $\mu^*_i = \theta^*_{2i} - \bar{\theta}_{2i} + \xi(\theta_{1i} - \bar{\theta}_{1i})$.

decision about whether or not to pool resources. If $P_{Q2i} < 0$, i.e., equity is worthless, then the bank clearly wants to pool resources. If $P_{Q2i} > 0$, so the bank is solvent, then depositors could be paid off at par at the end of period one. In that case, at the end of period two, the equity earns:

$$P_{Q3i} = \frac{(1 + r)\theta_{2i}\{[D + Q] - D\}}{Q} = (1 + r)\theta_{2i} \ . \tag{17}$$

Notice that the decision of a solvent bank to pool resources or not is not based on comparing the expected value of (16) with the expected value of (17). In particular, (16) does not subtract the losses which other banks are expected to earn, but which bank i is going to be partially responsible for if resources are pooled.

Stability of the pooling CHC will turn out to depend on whether solvent banks always choose to pool or not. Suppose there is a panic at the beginning of period two, and suppose there are m insolvent banks out of a total CHC membership of size n. Because of the serial correlation of the portfolio shocks, these banks are expected to be insolvent at the end of period two. The expected losses of the CHC, then, are:

$$\Delta \equiv \sum_{j=1}^{m} \int_{\underset{\sim}{\mu}}^{\mu_j^*} \{[(1 + r)(D + Q)(\bar{\theta}_{2j} + \xi(\theta_{1j} - \bar{\theta}_{1j}) + \mu_j)] - (1 + r_d)D\} Z(\mu)d\mu \ .$$

The assumed sharing rule is that solvent banks are responsible for these losses in proportion to each bank's value as a fraction of the total earnings of all solvent banks. In other words, bank i's share of the losses is expected to be:

$$S_i \equiv \frac{\int_{\mu_i^*}^{\tilde{\mu}} \{[(1+r)(D+Q)(\bar{\theta}_{2i} + \xi(\theta_{1i} - \bar{\theta}_{1i}) + \mu_i)] - (1 + r_{di})D\}Z(\mu)d\mu}{\sum_{k=1}^{n-m} \int_{\mu_k^*}^{\tilde{\mu}} \{[(1+r)(D+Q)(\bar{\theta}_{2k} + \xi(\theta_{1k} - \bar{\theta}_{1k}) + \mu_k)] - (1 + r_{dk})D\}Z(\mu)d\mu}$$

So, $S \equiv \{S_i: \; i = 1, \ldots, n\}$ is the sharing rule. Define the ratio of expected member losses to expected member profits:

$$\theta \equiv \frac{\sum_{j=1}^{m} \int_{\underset{\sim}{\mu}}^{\mu_j^*} \{[(1+r)(D+Q)(\bar{\theta}_{2j} + \xi(\theta_{1j} - \bar{\theta}_{1j}) + \mu_j)] - (1 + r_{dj})D\}Z(\mu)d\mu}{\sum_{k=1}^{n-m} \int_{\mu_k^*}^{\tilde{\mu}} \{[(1+r)(D+Q)(\bar{\theta}_{2k} + \xi(\theta_{1k} - \bar{\theta}_{1k}) + \mu_k)] - (1 + r_{dj})D\}Z(\mu)d\mu}$$

Note that $\theta \le 1$ means that the CHC expects to be solvent at the end of period two. In the case of $\theta > 1$, the CHC does not expect to be able to pay off loan certificates at par. (Possibly there are other pooling arrangements, so the following proposition only provides sufficiency.)

<u>PROPOSITION 6</u>: If, at $t = 0$, bank debt-equity ratios satisfy:

$$\theta_{1i}^* \equiv \frac{D}{D+Q} < \bar{\theta}_1 - \bar{\theta}_2/\xi , \quad \forall i , \tag{18}$$

then the pooling CHC is stable.

<u>Proof</u>: If there is a banking panic at the beginning of period two, then the CHC is in one of four possible situations: (1) all member banks are insolvent, i.e., $\theta_{1i} < \theta_{1i}^*$, $\forall i$; (2) all member banks are solvent, i.e.,

Consider the decision of a solvent bank. If a solvent bank pays off depositors at t = 2, then the expected equity return is given by the expectation of (17). If, instead, the bank pools, the expected return is given by the expectation of (16) minus $S_i\Delta$, i.e., bank i's share of the losses. Thus, bank i will only agree to pool if:

$$\int_{\mu_i^*}^{\tilde{\mu}} \{(1+r)(D+Q)[\bar{\theta}_{2i} + \xi(\theta_{1i} - \bar{\theta}_1) + \mu_i] - (1+r_d)D\}Z(\mu)d\mu$$
$$- (1+r)Q \int_{\underset{\sim}{\mu}}^{\tilde{\mu}} [\bar{\theta}_{2i} + \xi(\theta_{1i} - \bar{\theta}_1) + \mu]Z(\mu)d\mu > S_i\Delta \ . \quad (19)$$

Dividing through by bank i's expected profits in the absence of the panic or pooling, (22) becomes:

$$1 - \frac{(1+r)Q \int_{\underset{\sim}{\mu}}^{\tilde{\mu}} [\bar{\theta}_{2i} + \xi(\theta_{1i} - \bar{\theta}_1) + \mu]Z(\mu)d\mu}{\int_{\mu_i^*}^{\tilde{\mu}} \{(1+r)(D+Q)[\bar{\theta}_{2i} + \xi(\theta_{1i} - \bar{\theta}) + \mu_i] - (1+r_{di})D\}Z(\mu)d\mu} > \Theta \ . \quad (20)$$

Because of the serial correlation, a solvent bank at the end of period one would never prefer to pay off depositors early. Consequently, the left-hand side of (20) is never greater than 1. Therefore, a solvent bank will never agree to pool if $\Theta > 1$, i.e., if the CHC is not expected to be solvent.

In case (1), above, all members are insolvent, Θ is undefined, and all members will agree to issuing loan certificates. In case (2), all member banks are solvent, so $\Theta = \Delta = 0$, and by (19) or (20) all banks agree to issue loan certificates. In case (3), (20) does not hold, solvent banks expect to

Case (4) is difficult because, for a bank which is just solvent at the end of period one, the expected gain to pooling may be less than choosing to pay off depositors. If a single bank does this, then depositors cannot distinguish case (3) from case (4) and the CHC will collapse. Consider such a marginal bank, i.e., a bank whose end of period one state is exactly θ^*_{1i}, a just solvent bank. And suppose $\theta = 1$, i.e., the worst CHC scenario without insolvency. Then this bank will choose to pool only if (18), the condition of the proposition holds. The condition is derived from setting $\theta_{1i} = \theta^*_{1i}$ and $\theta = 1$ in (20). ‖

Proposition (6) determines the equity-debt ratio which must be imposed under the deposit contract. λ_D is the Lagrange multiplier previously associated with this. Since all banks are identical with respect to quantities, the requirement of the CHC that all banks promise the same maximum rate of return on demand deposits prevents banks from satisfying (18) but free riding on the insurance by offering a higher rate of return. Interest rate ceilings are necessary for CHC stability.

Pareto-Superiority of the Coalition Over the Market

If the pooling CHC is stable at the end of period one, in the event of panic, then there remains the question of stability at the beginning of the world. That is, does every bank have an incentive to join the CHC initially? And who enforces the minimum equity-debt ratio? To answer these questions, first note that, not surprisingly, depositor-households are better off with insurance.

PROPOSITION 7: If a banking panic is possible, then with CHC insurance the

Proof: See Appendix.

With insurance coverage households are better off because they are insured against mistakenly withdrawing.

Now consider which contract, the note contract or the deposit contract, will be chosen at t = 0. Households can observe whether banks are members of the coalition or not. Proposition 8 shows that if households prefer the deposit contract, given the CHC, then the CHC has the power to threaten members in such a way that the CHC is stable.

PROPOSITION 8: The cooperative CHC is stable if and only if households choose the demand deposit contract, given the existence of the CHC.

Proof: First, we will show that the cooperative solution of the CHC can be supported by the credible threat of the noncooperative note contract equilibrium if households choose the demand deposit contract. Assuming the CHC, households choose the deposit contract if:

$$E_0[MVO_d|CHC]-E_0[MVO_N] - [\frac{\lambda_D - \lambda_N}{\beta^2 b}] > 0 \ . \tag{21}$$

Then, if (24) holds, any bank not in the CHC cannot operate because no household wants the note contract. The best response of a single bank, given that all other banks are in the CHC, is to join.

Second, if households choose the deposit contract assuming the CHC, then the deposit contract dominates the note contract and the deposit contract without the CHC. Then, again, no bank can operate without being in the CHC. ||

Proposition 8 says that households can rely on their banks to enforce contracts on their behalf against other banks if such mutual enforcement makes the deposit contract the preferred contract. In order for the CHC to be able to issue loan certificates, should a panic occur, the minimum equity-debt ratio, (18), and the interest rate ceilings must be enforced. Each CHC member has an incentive to enforce these constraints against all other members because of the possibility of issuing loan certificates. But the CHC also has a credible threat, namely, expulsion.

Also of particular note is how the two contracts are linked. The CHC is a contract among banks. Households only observe the parties to this contract. However, the incentive compatibility of the deposit contract, between households and their particular banks, depends upon the unobserved workings of the CHC, in particular, bank states and enforcement of overissuing. Conversely, the CHC contract is only incentive compatible among banks if, given the CHC contracts, the contracts between households and their particular banks are incentive compatible. We formalize this point as follows.

<u>DEFINITION 8</u>: Households are said to have <u>confidence</u> in the banking system if they choose the demand deposit contract and rely on the CHC to enforce (18) so that (21) holds.

We can now state, in summary:

THEOREM 2: If confidence exists, then closing the rate market is Pareto preferred. In fact, if the debt-equity ratio required by the clearing house is lower than that required for notes, then the constraint may not be binding. Households may be willing to invest that much for period three anyway. In that case, agency costs for deposits with the CHC are zero.[5]

V. Conclusion

In games, cooperation can often be induced, and Pareto-superior outcomes achieved, if the assumption of common knowledge is broken in the right way. Here, under the note contract the market creates common knowledge, making the note contract viable, but costly. The alternative deposit contract and CHC break the common knowledge created by the market, and consequently cause information externalities, inducing cooperative behavior among the banks. Bank cooperation together with depositor choices given cooperation reduce the agency costs. The cooperative arrangement, supported by the noncooperative threat of opening the efficient market, is a Pareto improvement.

These results complement the recent work of Diamond (1984) and Boyd and Prescott (1986), but contrast with the work of Diamond and Dybvig (1983) and Fama (1980). In the former works intermediaries arise to eliminate a duplication of effort by many lenders. An intermediary coordinates these efforts, becoming the single monitor or information producer, selling claims to the many lenders, and, in turn, lending on their behalf. The important feature of this solution is that "monitoring the monitor" is solved through diversification. The intermediary's monitoring performance can be monitored simply by observing the intermediary's pay-off to depositors. If the intermediary's portfolio is fully diversified, then it can always pay off insurance, or complete diversification, occurs, in the present study, only through cooperation of the banks, who, as an industry, are diversified (against nonsystematic risk) and can, thus, be monitored. The market cannot achieve this, and this is the basis for superiority of the cooperative solution.

But the present work contrasts with Diamond and Dybvig (1983) and Fama (1980). In Diamond and Dybvig (1983) the existence of banks is taken to mean that an inherent problem with banking panics arises, leading to government insurance. Fama (1980) has the opposite view, namely, that government intervention into the banking industry is arbitrary since there is no market failure. In the present work (with some exaggeration) households are offered a Fama-type economy, but choose a world in which there is an inherent problem of banking panics. Unlike Diamond and Dybvig, however, this is not grounds for government intervention nor is the problem inherent to bank contracts. Here, by endogenously creating the problem of a "market failure," the economy creates an incentive-compatible, but private, regulatory system.

APPENDIX

Proof of Proposition 2

From the first order conditions (9) and (10) of the main text, household j will withdraw deposits, and switch to gold, if:

$$\frac{P^e_{d3j}(1 + r_{dj}) - \lambda_D}{P^e_{d2j}} < 1 \qquad \text{(A1)}$$

because, if (A1) holds, the rate of return on gold is higher than the expected rate of return on deposits. Recall that $\theta_{1j} \equiv \varepsilon_{1j} + \lambda_1$, and $\theta^*_{1j} = \frac{D}{D + Q}$. λ_1 is known. Define $\varepsilon^*_1 = \frac{D}{D + Q} - \lambda_1$ to be the lowest possible realization of ε^*_1 such that there is no capital loss on deposits. Then:

$$P^e_{d2j} = \int_{\varepsilon^*_1}^{\tilde{\varepsilon}_{1j}} f(\varepsilon_{1j})d\varepsilon_{1j} + \int_{\underset{\sim}{\varepsilon}_{1j}}^{\varepsilon^*_1} [\frac{D + Q}{D}][\lambda_1 + \varepsilon_{1j}]f(\varepsilon_{1j})d\varepsilon_{1j} \qquad \text{(A2)}$$

where $f(\varepsilon_{1j})$ is the density function and the support of the distribution is $[\underset{\sim}{\varepsilon}_{1j}, \tilde{\varepsilon}_{1j}]$. Recalling the definition of μ^* from above:

$$P^e_{d3j} = \int_{\underset{\sim}{\varepsilon}_{1j}}^{\tilde{\varepsilon}_{1j}} \int_{\mu^*}^{\tilde{\mu}} Z(\mu)f(\varepsilon_{1j})d\mu d\varepsilon_{1j} +$$

$$\int_{\underset{\sim}{\varepsilon}_{1j}}^{\tilde{\varepsilon}_{1j}} \int_{\underset{\sim}{\mu}}^{\mu^*} [\frac{(1 + r)(D + Q)}{(1 + r_d)D}]\{\bar{\theta}_2 + \qquad \text{(A3)}$$

$$\xi[\varepsilon_{1j} + \lambda_1 - (\bar{\varepsilon}_1 + \bar{\lambda}_1)] + \mu\}Z(\mu)f(\varepsilon_{1j})d\mu d\varepsilon_{1j} .$$

Note, ε_{1j} can be eliminated by integrating. λ^{**}_1 is found by substituting (A2) and (A3) into (A1) and solving for λ_1 such that (11) holds as an equality.

is such that $\lambda_1 < \lambda_1^{**}$, households at all locations withdraw gold from all banks. ‖

Proof of Proposition 3

By Proposition 1, the household will switch from notes to gold if $\lambda_1 < \lambda_{1j}^{*}$. By Proposition 2, the household will switch from deposits to gold if $\lambda_1 < \lambda_1^{**}$. Given these rules the expected value of the option (VO) on notes and deposits, can be respectively defined as follows.

$$E_0(VO_N) = \int_{\underset{\sim}{\mu}}^{\tilde{\mu}} \int_{\underset{\sim}{\varepsilon}_1}^{\tilde{\varepsilon}_1} \int_{\underset{\sim}{\lambda}_1}^{\lambda^*(\varepsilon_1)} \beta\{a + b[G_3 + (1 + r)\theta_{2j}I + (1 + r_{Qj})Q_j]\}$$

$$f(\lambda_1)f(\varepsilon)Z(\mu)d\lambda_1 d\varepsilon d\mu - \int_{\underset{\sim}{\mu}}^{\tilde{\mu}} \int_{\underset{\sim}{\varepsilon}_1}^{\tilde{\varepsilon}_1} \int_{\underset{\sim}{\lambda}_1}^{\lambda^*(\varepsilon_1)} \beta\{a + b[M_{j+1}(P_{3j+1}(1 + r_N) \tag{A4}$$

$$+ (1 + r)\theta_{2j}I + (1 + r_{Qj})Q_j]\}f(\lambda_1)f(\varepsilon)Z(\mu)d\lambda_1 d\varepsilon d\mu$$

$$E_0(VO_d) = \int_{\underset{\sim}{\mu}}^{\tilde{\mu}} \int_{\underset{\sim}{\varepsilon}_1}^{\tilde{\varepsilon}_1} \int_{\underset{\sim}{\lambda}_1}^{\lambda_1^{**}} \beta\{a + b[G_3 + (1 + r)\theta_{2j}I + (1 + r_{Qj})Q_j]\}$$

$$f(\lambda_1)f(\varepsilon)Z(\mu)d\lambda_1 d\varepsilon d\mu - \int_{\underset{\sim}{\mu}}^{\tilde{\mu}} \int_{\underset{\sim}{\varepsilon}_1}^{\tilde{\varepsilon}_1} \int_{\underset{\sim}{\lambda}_1}^{\lambda_1^{**}} \beta\{a + b[D_3(P_{d3j}(1 + r_d)) \tag{A5}$$

$$+ (1 + r)\theta_{2j}I + (1 + r_{Qj})Q_j\}f(\lambda_1)f(\varepsilon)Z(\mu)d\lambda_1 d\varepsilon d\mu \ .$$

Definitions (A4) and (A5) correspond to Definition 2 of the main text, i.e., the value of the option is the difference in utility between withdrawing gold and not withdrawing when the strategy of withdrawing is optimal.

maximization problem is omitted. The first order conditions for gold, notes, and deposits, are:

$$U'_{c1} - \beta^2 bP_1 \geq 0 \qquad (= \text{ if } G_1 > 0) \qquad (A6)$$

$$U'_{c1} - \beta^2 b\{P^e_{3Nj}(1 + r_N) - \frac{\lambda_N}{\beta^2 b} + E_0[MVO_N]\}P_1 \geq 0 \qquad (= \text{ if } M_{1j} > 0) \qquad (A7)$$

$$U'_{c1} - \beta^2 b\{P^e_{3dj}(1 + r_{dj}) - \frac{\lambda_D}{\beta^2 b} + E_0[MVO_d]\}P_1 \geq 0 \qquad (= \text{ if } D_1 > 0) \qquad (A8)$$

where: $$E_0[MVO_N] \equiv \frac{\partial E_0[VO_N]}{\partial M_{1j}} \; ; \quad E_0[MVO_d] \equiv \frac{\partial E_0[VO_d]}{\partial D_{1j}} \; .$$

As before, the equilibrium will either be notes or deposits, and equation (11) of the main text is found by comparing (A7) and (A8). ‖

Proof of Proposition 4

Note that if the household seller withdraws gold from the bank at the end of period two, then the amount of gold received is equal to the value of the notes turned in, i.e., $G_3 = M_{3j+1}P_{2j+1}$ $(= S_2P_2)$. Similarly, if all deposits are withdrawn then the amount of gold received is: $G_3 = D_{3j}P_{2dj}$ $(= S_2P_2)$. Using these budget constraints, substitute for G_3 in (A4) and (A5). Then the expected marginal value of the option to withdraw, in the cases of notes and deposits, respectively, is:

$$E_0(MVO_N) = \int_{\underset{\sim}{\mu}}^{\tilde{\mu}} \int_{\underset{\sim}{\varepsilon}_1}^{\tilde{\varepsilon}_1} \int_{\underset{\sim}{\lambda}_1}^{\lambda^*(\varepsilon_1)} \beta b\{P_{2j} - [P_{3j}(1 + r_N)]\}f(\lambda_1)f(\varepsilon_1)Z(\mu)d\lambda_1 d\varepsilon_1 d\mu \qquad (A9)$$

$$E_0(MVO_d) = \int_{\underset{\sim}{\mu}}^{\tilde{\mu}} \int_{\underset{\sim}{\varepsilon}_1}^{\tilde{\varepsilon}_1} \int_{\underset{\sim}{\lambda}_1}^{\lambda_1^{**}} \beta b\{P_{2dj} - [P_{3dj}(1 + r_d)]\} f(\lambda_1) f(\varepsilon_1) Z(\mu) d\lambda_1 d\varepsilon_1 d\mu \; . \tag{A10}$$

In computing the difference between (A9) and (A10), there are three cases to consider: (1), $\lambda_1^{**} < \lambda^*(\varepsilon_{1j+1}), \forall\varepsilon_{1j+1}$, (2), $\lambda_1^{**} > \lambda^*(\varepsilon_{1j+1}), \forall\varepsilon_{1j+1}$; or (3), λ_1^{**} intersects $\lambda^*(\varepsilon_{1j})$, say from above without loss of generality, i.e., there exists $\hat{\varepsilon}_{1j}$ such that $\lambda_1^{**} = \lambda^*(\hat{\varepsilon}_{1j})$. The last case contains the first two. See Figure 1. In case (3),

$$E_0(MVO_N) - E_0(MVO_d) = \int_{\underset{\sim}{\mu}}^{\tilde{\mu}} \Big\{ \int_{\underset{\sim}{\varepsilon}_1}^{\hat{\varepsilon}_1} \int_{\lambda^*(\varepsilon_{1j})}^{\lambda_1^{**}} \beta b[P_{2dj} - (P_{3dj}(1 + r_d))] f(\lambda_1) f(\varepsilon_1) d\lambda_1 d\varepsilon_1 \tag{A11}$$

$$+ \int_{\hat{\varepsilon}_1}^{\tilde{\varepsilon}_1} \int_{\lambda_1^{**}}^{\lambda^*(\varepsilon_{1j})} \beta b[P_{2j+1} - (P_{3j+1}(1 + r_N))] f(\lambda_1) d\varepsilon_1 \Big\} Z(\mu) d\mu$$

But $P^e_{2dj} > P^e_{3dj}\,(1 + r_d)$ if $\lambda_1 < \lambda_1^{**}$, by Proposition 2, and $P^e_{2j+1} > P^e_{3j+1}(1 + r_N)$ if $\lambda_1 < \lambda^*_{1j}$, by Proposition 1. (Recall, $\lambda_D = \lambda_N = 0$ is assumed.) Therefore, $E_0(MVO_d) < E_0(MVO_N)$. ||

Proof of Proposition 7

If a banking panic is possible such that households withdraw deposits when they would not if they had full information, then clearly depositors are better off, *ceteris paribus*, because this mistake is avoided. (See Figure 1.) (A more formal proof is left to the reader.) ||

Footnotes

[1]The model in Gorton (1987) is more complicated because of an endogenous court system. This makes it impossible to verify the optimality of the contract in Definition 1 in the present setting.

[2]In Figure 1 there need not be an intersection point. In what follows it is assumed that, under the deposit contract, there exists the possibility of withdrawing when households would not withdraw under the note contract.

[3]Notice that, in the event of panic, the signalling action taken by a separating CHC must be costless because there are no available resources to expend unless investments are to be liquidated.

[4]The explanation of loan certificates that follows is the procedure used by U.S. clearinghouses during nineteenth century panics. See Gorton (1985B), Gorton and Mullineaux (1986), Timberlake (1984).

[5]If agency costs are zero under the CHC, then we may ask whether the CHC can implement the first best allocation. With insurance households can hold more of their savings in the form of deposits, maximizing insurance coverage, and avoiding the mistake of not withdrawing deposits when they would if they had full information. This is feasible as long as the minimum debt-equity ratio, (18), is not violated. With a higher level of deposits, households will panic over more states of λ_1 than before. However, bank long-term investments are never liquidated under any conditions. Thus, the first best allocation cannot be achieved unless the CHC is capable of forcing some member banks to liquidate, but then the rule of governing this would have to be agreed to at $t = 0$. But, this is a separating equilibrium and can be ruled out with an argument similar to the proof of Proposition 5.

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FIGURE 1

<u>Comparison of Decision Rules</u>