Bank Runs: Speculative Runs and Fundamental Runs*

Seonghwan Oh
Seoul National University
Jeffrey Wrase
Arizona State University

This paper analyzes deposit contracts when banks face alternative types of bank runs. The bank in our model can prevent speculative types of bank runs, which arise when depositors believe that deposit withdrawal volume will lead the bank into insolvency, by designing contracts that allow for payment suspension. However, suspension does not eliminate fundamental runs which arise when depositors calculate, given new information revealing low returns, that deposit withdrawal dominates deposit retention. The bank can eliminate fundamental runs by restricting payments. Then, deposit claim depreciation depends on expected returns and withdrawal volume prior to restriction.

I. Introduction

In recent models of financial intermediation and bank runs including those by Diamond and Dybvig (1983), Freeman (1989), Waldo (1985), and Wallace (1988) financial intermediaries insure agents against an unexpected demand for liquidity. In Diamond and Dybvig (DD), for example, agents face intertemporal consumption preference shocks which are not publicly verifiable, ruling out a complete market of Arrow-Debreu state-contingent claims. Given the resulting random demand for liquid assets and lower returns on liquid assets than illiquid assets, there is room for a financial intermediary, referred to as a bank, that holds illiquid assets and issues liquid liabilities.

The bank implements the aggregate production plan, i.e. the

allocation between liquid and illiquid investments, and issues liabilities called demand deposit contracts. DD investigate strategic decisions that depositors face and two, Pareto-ranked, Nash equilibria. One, a Pareto-dominant equilibrium, has only depositors with genuine preference for early consumption withdrawing early. The second, a Pareto-dominated speculative bank run equilibrium, has depositors who actually prefer late consumption, fearing withdrawal by others of the same type, also withdrawing early. Inefficiency of the run equilibrium results from premature disinvestment of the higher yielding illiquid assets. DD assume deterministic investment returns allowing them to address only speculative runs.

This paper generalizes the DD model by introducing stochastic investment returns, and explicitly analyzes an environment with stochastic proportions of agents with preference for early and late consumption. We derive an optimal consumption allocation available to agents from the bank and consider incentives for depositors to run if the bank attempts to implement this allocation using ordinary demand deposit contracts. We then consider alterations of deposit contracts to eliminate incentives to run.

The bank faces possibilities of fundamental runs, and two types of speculative runs when ordinary deposit contracts are used. One type of speculative run is the type considered by DD which arises if agents with *genuine* preference for late consumption choose early withdrawal based on speculation that other late consumers will do likewise. The second originates from a mixture of speculation and fundamentals and arises from depositors' speculation that even if late consumers do not withdraw early random liquidity demand by early consumers will be such that early payments from the bank will exceed late payments. A fundamental run arises when depositors calculate, based on interim information revealing low future returns on the bank's portfolio, that payments on late withdrawals will fall below payments promised on early withdrawals.

We find that while a deposit contract allowing for suspension of early payments is not sufficient to rule out speculative runs and implement the optimal banking allocation, the bank can use suspension contracts to implement an allocation superior to autarky. To eliminate speculative runs the bank trades off provision of risk sharing available in the banking allocation against provision of incentives for late consumers not to run.

We also find that while contracts allowing for suspension cannot eliminate fundamental runs, the bank can remove incentives to par-

ticipate in such runs by designing deposit contracts that allow for restricted payments. When payments are restricted, depositors requesting early withdrawal receive positive payments below the contractually promised payments. The extent to which restricted payments fall below promised payments depends on how poorly the bank's portfolio performs, as signalled by interim information, and on the volume of withdrawal requests that have been serviced prior to receipt of return information. Restricted payments are structured so that deposit retention is the dominant strategy for depositors with preference for late consumption.

Our analysis of restricted payments is interesting in light of past financial crises in which banks restricted, rather than suspended, payments to depositors (Sprague 1910, pp. 66, 182, 287). In addition, when payments are restricted the depreciation of deposit claims depends on the bank's portfolio performance and on withdrawal volume prior to restriction. The model therefore provides some justification for the existence of currency premiums during financial crises (Sprague 1910, p. 187).

The remainder of the paper proceeds as follows. Section II specifies the economic environment. Section III discusses functions of the bank, design of deposit contracts in the face of potential speculative runs, and compares outcomes under autarky and banking when the fraction of depositors who turn out to be early consumers is stochastic and not known when contracts are designed. Section IV analyzes deposit contracts in a general environment where investment returns are subject to aggregate and idiosyncratic disturbances and where fundamental runs arise. Section V concludes.

II. A Three Period, Single Good Economy

The model has a single good and three periods: a planning and investment period, and two periods of production and consumption.[1] There are a countable infinity of agents and investment projects. Each agent is endowed with one unit of the good in period 0 and none in other periods. Investment in a project occurs in period 0 and returns are realized in the following two periods. A one–unit minimum is required for investment in any one project. Agents also have access to a storage technology that costlessly carries the good for-

---

[1]Engineer (1989) considers speculative runs and suspension in a four period, three-agent type model where different agents discover their types at different times.

ward from one period to the next.

Each project has an idiosyncratic period 2 disturbance, $\theta \in [\underline{\theta}, \overline{\theta}]$ which has expected value of zero. With a countable infinity of projects there is no aggregate disturbance to period 2 returns. Section IV generalizes to an environment with idiosyncratic and aggregate return disturbances. A project initiated in period 0 yields $R(\theta) = R + \theta$, $R > 1$, if allowed to continue into period 2, or $1 - \varepsilon$ if terminated in period 1, where $\varepsilon \in (0, 1)$ reflecting partial reversibility of investment.

Partial reversibility is assumed for two reasons. First, complete irreversibility, $\varepsilon = 1$, eliminates speculative bank runs since returns from illiquid assets cannot be realized early even in a run. Assuming $\varepsilon < 1$ allows for the possibility of runs. Second, with complete reversibility, $\varepsilon = 0$, projects would be perfectly liquid in that early reversal recovers the full amount invested. Assuming $\varepsilon > 0$ provides a clear notion of the illiquidity of production investments relative to storage.[2]

Agents are all together in periods 0 and 2 but are spatially isolated in period 1 as in Wallace (1988). During period 1 each agent intersects a centrally located financial intermediary, which we call a bank, at some instant and chooses to withdraw or retain a deposit claim for period 2 withdrawal. Thus, if agents choose to hold deposit claims the bank must sequentially service depositors' period 1 withdrawal requests. Each agent knows that her time of arrival at the bank in period 1 is random and that arrival times are uniformly distributed.[3]

There are two types of agents. Type 1 agents care only about period 1 consumption while type 2 care only about period 2 consumption. Agents do not know their types in the planning period but discover them in period 1. Knowledge of one's type is private information. Thus, an agent in period 0 faces an uninsurable risk of

---

[2]DD use a different notion of liquidity. What they refer to as an illiquid asset, if "liquidated" early, provides the same return as the liquid asset. Their notion of illiquidity reflects a foregone opportunity to earn a future return above the return from early termination of a project, not an inability to recover the full amount invested through early reversal.

[3]The isolation assumption rules out securities markets in which each agent invests in a project, issues shares, and purchases equal claims on all projects to diversify. As Wallace points out, the isolation assumption is consistent with the idea that agents hold liquid demand deposits for consumption at random times and places (they cannot, then, all be together) when they do not have access to asset market.

becoming type 1 in period 1. The state-dependent utility function for agent j has the form,

$$u(c_1, c_2) = \begin{cases} u(c_1) & \text{if } j \text{ is type } 1 \\ u(c_2) & \text{if } j \text{ is type } 2, \end{cases}$$

where c_k represents units consumed in period k. $u(\cdot)$ is twice continuously differentiable, increasing, and strictly concave, with $u'(0) = \infty$, and $u'(\infty) = 0$. Given the corner nature of agents' conditional preferences, type 1's consume only in period 1 and type 2's only in period 2.

A fraction $t \in [0, \bar{t}]$ of all agents turn out to be type 1, where $\bar{t} < 1$, and t is a continuously distributed random variable with strictly positive density function $g(t)$. To make the analysis interesting we assume that agents can *not* observe the true value of t that is realized in period 1. Accordingly, contracts contingent on the realization of t cannot be written. A random fraction t allows us to consider effects of aggregate liquidity shocks on the banking system.

With unit endowments, unit investment requirements, and no securities markets, an individual cannot diversify away idiosyncratic return risks by investing equally in all projects. We assume that liquidation penalty ϵ and project return risks are large enough that expected utility for an autarkic agent from investment in the nonstochastic storage technology is above that from direct investment in one of the risky projects.

III. Deposit Contracts and Speculative Runs

If agent types were publicly verifiable and if the realization of t was *known* as of period 1 it would be possible for the bank to pool endowments, form a diversified portfolio, and write insurance contracts that provide optimal risk sharing between type 1 and type 2 agents. In fact, even with nonverifiable types, if the realized t could be observed then optimal risk sharing could be implemented using contracts with period 1 payments to agents claiming to be type 1 and (higher) period 2 payments each contingent on t and with suspension of period 1 payments when the fraction of all agents requesting early payment reaches the realized value to t.

However, agents cannot write contracts with such contingencies since t is *unknown*. With nonverifiable agent types and an unknown

realization of t our interest is in whether a bank can implement a
consumption allocation that provides benefits of risk sharing and
improves on the allocation available to agents under autarky.

As a benchmark, consider the optimal consumption allocation that
the bank could implement if individual types, once realized in period
1, were publicly verifiable and with all agents of a given type re-
ceiving equal consumption. With verifiable types, the bank could
make early payments to type 1 depositors only. However, given se-
quential servicing of early withdrawal requests and unknown t, the
bank cannot make early payments depending on total period 1 with-
drawal volume.[4]

While the benchmark banking allocation provides depositors with
risk sharing improvements over autarky an ordinary demand deposit
contract cannot implement the allocation as a unique dominant
strategy Nash equilibrium. Given the strategic decisions facing de-
positors that are identified below, the bank must trade off provision
of some risk sharing benefits available in the benchmark allocation
against provision of incentives for type 2 depositors not to request
early deposit withdrawal.

To illustrate this tradeoff we first derive the benchmark banking
allocation and then discuss its implementation. In deriving the ben-
chmark allocation note that with early liquidation costs the bank
will store, as "reserves", part of the endowment pool to provide
units of the good to type 1 depositors without need for premature
investment liquidation. Two contingencies must be considered since t
is not observed. In one, reserves exceed the amount necessary to
provide planned period 1 consumption to type 1 depositors. The
excess reserves can be stored and paid out in period 2. In the other,
reserves are not sufficient to provide planned consumption to type 1
depositors and projects must be liquidated.

The benchmark banking allocation choice can be represented as a
planning problem of choosing reserves and the consumption alloca-
tion to maximize a representative depositor's expected utility sub-
ject to the aggregate resource constraint. The allocation involves
$\{c_1^*, c_2^E, c_2^I, S^*\}$, where c_1^* is period 1 consumption, c_2^E is period 2
consumption in the excess reserve outcome, c_2^I is period 2 consump-
tion in the insufficient reserve outcome, and S^* is reserves per unit

---

[4]Diamond (1984), Townsend (1979), Williamson (1986), and Postlewaite and Vives
(1987) discuss possible reasons for banks' historical use of noncontingent deposit pay-
ments.

deposit. This allocation solves

$$\max_{S, c_1} \int_0^{\bar{t}} [tu(c_1) + (1 - t)u(c_2)] g(t) dt \tag{1}$$

$$\text{subject to} \quad (1 - t)c_2^E = (1 - S)R + (S - tc_1) \quad \text{for } S \geq tc_1 \tag{2}$$

$$(1 - t)c_2^I = \{(1 - S) - \delta(tc_1 - S)\} R \quad \text{for } S < tc_1, \tag{3}$$

where $\delta = \dfrac{1}{1 - \epsilon}$. According to the first order conditions for (1) the banking allocation satisfies

$$\int_0^{\bar{t}} tu'(c_1^*) g(t) dt = \int_0^{t^*} tu'(c_2^E) g(t) dt + R \delta \int_{t^*}^{\bar{t}} tu'(c_2^I) g(t) dt \tag{4}$$

$$(R - 1) \int_0^{t^*} u'(c_2^E) g(t) dt = R(\delta - 1) \int_{t^*}^{\bar{t}} u'(c_2^I) g(t) dt \tag{5}$$

where

$$c_2^E = \frac{(1 - S^*)R - (S^* - tc_1^*)}{1 - t}$$

$$c_2^I = \frac{\{(1 - S^*) - \delta(tc_1^* - S^*)\} R}{1 - t},$$

$$\text{and} \quad t^* = \frac{S^*}{c_1^*}.$$

Given reserves S^* and probabilities of ending up with either excess or insufficient reserves, (4) says that the consumption plan balances appropriately weighted expected marginal utilities of period 1 and period 2 consumption. Weight $R\delta$ on expected marginal utility of c_2^I reflects costs from early investment liquidations to provide c_1^* to type 1 depositors given a reserve deficiency. The weight on expected marginal utility of c_2^E is one since period 2 consumption increases one for one with the excess of reserves over the amount necessary to provide c_1^* to type 1 depositors.

Condition (5) says that given the consumption plan and the probabilities of either excess or insufficient reserves, optimal reserves S^* balance appropriately weighted expected marginal utilities of period 2 consumption in the excess and insufficient reserve outcomes. Weight $(R - 1)$ on expected marginal utility of c_2^E reflects opportunity costs implied by excess reserves, and weight $R(\delta - 1)$ on expected marginal utility of c_2^I reflects costs from early project liquidations to provide c_1^* to type 1 depositors.

Observe that if $c_1^* \geq \dfrac{R}{t^*R - t^* + 1}$ then c_1^* is always greater than c_2^* which implies that early withdrawal would be the dominant strategy for *all* depositors. Thus, it must be that $c_1^* < \dfrac{R}{t^*R - t^* + 1} (> 1)$ which, in turn, implies that $dc_2^E/dt > 0$ and $c_2^E > c_1^*$ for all $t \in [0, t^*]$. Also observe that if $c_1^* > \dfrac{1 - \epsilon}{1 - t^* \epsilon} (< 1)$ then $dc_2^I/dt < 0$ for all

$t \in [t^*, \bar{t}]$. We assume that $c_1^* > 1$ to highlight the role of the bank as a provider of liquidity to type 1 depositors. When period 1 payments exceed unity, and implied period 2 payments are therefore below the long term return of R, an allocation is implemented which dominates autarky and provides risk sharing to depositors.

When t is deterministic, the banking allocation above reduces to the optimal risk sharing allocation in DD. As DD show, in this case a suspension contract eliminates speculative runs and is sufficient for achieving optimal risk sharing. When t is stochastic, however, suspension is not sufficient to eliminate speculative runs. Observe that if suspension occurs when the number of early withdrawals as a fraction of all depositors reaches some value below $\bar{t}$ then, since the realized value of t is not known, there is a positive probability that some type 1 depositors will not be able to withdraw in period 1. We therefore consider a contract allowing for suspension at $\bar{t}$.

Propositon 1
A speculative run can arise if the bank attempts to implement the benchmark banking allocation using a deposit contract with suspension of period 1 payments at $\bar{t}$.

For proof, recall that $dc_2^J / dt < 0$ and consider the worst possible case for a type 2 of $t = \bar{t}$. It is easy to show that c_2^J can be larger, equal to, or smaller than c_1^* when $t = \bar{t}$, depending on the value for c_1^* that satisfies (4) and (5).

In one case $c_2^J > c_1^*$ for all $t \in [t^*, \bar{t}]$. Then, since $c_2^E > c_1^*$ for all $t \in [0, t^*]$, if early payments are suspended at $\bar{t}$ the dominant type 2 strategy is deposit retention. Retention dominates early withdrawal since, independent of what an individual type 2 believes other type 2's will do, suspension ensures that late payments always exceed the early payment. Thus, in this case supension at $\bar{t}$ is sufficient to uniquely implement the banking allocation by ruling out speculate runs of the type considered by DD.

In the second case $c_2^J < c_1^*$ for a range $t \in [t', \bar{t}]$, where $\bar{t} > t' > t^*$. Then, even if period 1 payments are suspended at $\bar{t}$, a speculative run arises if depositors fear that the fraction of all depositors withdrawing early will be above t'. A sufficient condition for this second case to exist is $\varepsilon > \dfrac{R-1}{R}$ or $\delta > R$. Note that the type of speculative run considered in this case differs from the type considered in DD since t is a fundamental partial determinant of the size of late payments relative to early payments. Although t cannot be observed in our framewok, speculation or fear that the realized

liquidity demand will be sufficiently high can generate a bank run, and suspension at t is not sufficient to eliminate such a run.

Although a deposit contract with suspension at $\bar{t}$ cannot implement the banking allocation as a unique Nash equilibrium:

Proposition 2
The bank can design a suspension contract with consumption level $c_2^o > c_1^o > 1$ for all t with suspension at $\bar{t}$ that implements as a unique Nash equilibrium an allocation that dominates the autarky allocation.

For proof, let f denote the fraction of total deposits withdrawn in period 1. Suppose that the bank suspends period 1 payments at $\bar{t}$ and holds reserves $S^o = \bar{t}c_1^o$. It is easily determined that if $c_1^o < R/(\bar{t}R - \bar{t} + 1)$, then $c_2^o > c_1^o$ for all $f \leq \bar{t}$ and, since suspension occurs at $\bar{t}$, deposit retention is the unique dominant strategy for type 2 depositors. Note that $R/(\bar{t}R - \bar{t} + 1) > 1$ since $R > 1$ and $\bar{t} < 1$. Consequently, the bank can provide an allocation $c_2^o > c_1^o > 1$ with consumption levels that dominate those available in autarky.

The bank trades off provision of output sharing between type 1 and type 2 depositors that arises in the banking allocation against provision of incentives for type 2 depositors not to run. It is straightforward to show that relative to the banking allocation the bank provides lower period 1 consumption. Depending on the realized value of $f = t$, the period 2 payment can be above, equal to, or below the level associated with the benchmark banking allocation.[5]

IV. Deposit Contracts and Fundamental Runs

We now show that when aggregate return disturbances are included, the model generates restrictions consistent with at least one interpretation of the historical facts of bank runs. We incorporate aggregate disturbances by assuming that period 2 project returns are $R(\alpha, \theta) = \alpha R + \theta$. The idiosyncratic return disturbances θ net out across technologies, as before. The α disturbance is common to all projects where $\alpha \in [\underline{\alpha}, \bar{\alpha}]$ is a continuously distri-

---

[5]To eliminate incentives to run, DD argue that when t is stochastic contracts backed by deposit insurance prevent speculative runs and uniquely implement an optimal risk sharing allocation. However, the insurance scheme proposed by DD does not work in their model as Wallace (1988) points out. We consider only uninsured contracts since insurance will not in general improve on uninsured contract outcomes unless the insurer has an information advantage over banks along with power to levy taxes.

buted random variable with strictly positive density function $h(\alpha)$. We assume that α has expected value of 1 as of period 0, and that agents receive interim information in period 1 revealing the value of α that will be realized in period 2.

The interim information is assumed to arrive at some random time *during* period 1 while the bank is sequentially servicing early withdrawal requests. This assumption captures the idea that demand deposit contracts allow depositors to withdraw and consume at different random times without having to wait for an event such as return information arrival. Since information arrives at a random time after the bank has serviced some agents choosing to withdraw early, the bank is unable to write deposit contracts with all payments contingent on the interim information. The assumption that the interim information fully reveals, in period 1, the value of α that will be realized in period 2 simplifies the analysis. More generally, agents will face the problem of extracting information from noisy signals of banks' portfolio performances.

Given the more general stochastic structure of returns, a fundamental bank run can arise when depositors, upon receipt of new information about future returns, calculate that early withdrawals is the dominant type 2 strategy. A fundamental run does not arise simply from depositors' speculation but, rather, from new information about the bank's portfolio return performance.[6]

To focus on the role of the aggregate return disturbance we assume that t is known in period 0, and that depositors never participate in speculative runs since we have seen that contracts can be designed to rule out such runs.[7] As before, to provide a benchmark, we first determine the banking allocation that can be implemented if agents' types were publicly verifiable.

If types were publicly verifiable the bank could implement the banking allocation which solves

$$\max \int_{\underline{\alpha}}^{\bar{\alpha}} [tu(c_1) + (1-t)u(c_2)]h(\alpha)d\alpha \qquad (6)$$
$$\text{subject to} \quad (1-t)c_2 = \alpha(1-tc_1)R.$$

Since t is assumed here to be known in period 0, reserves per endowment unit will be $S = tc_1$. The first order condition for (6)

---

[6]Gorton (1985) provides an interesting analysis with an asymmetry of information about returns depositors and intermediaries in an environment that differs from ours in that Gorton's depositors and intermediaries have different objectives.

[7]Allowing t to be stochastic with contracts allowing for suspension at t does not change the qualitative nature of the results that follow.

reveals that the banking allocation involves reserves $\hat{S}$ and consumption levels $\hat{c}_1$ and $\hat{c}_2$ satisfying

$$u'(\hat{c}_1 = \frac{\hat{S}}{t}) = R\int_{\underline{\alpha}}^{\bar{\alpha}} \alpha\, u'(\hat{c}_2 = \frac{\alpha R(1 - t\hat{c}_1)}{1 - t})h(\alpha)d\alpha \, . \qquad (7)$$

A sufficient condition for $\hat{c}_1 > 1$ is $\alpha R > 1$ and relative risk aversion coefficient above one, which we assume hold in the cases analyzed below.[8] The bank could implement the above banking allocation if types were publicly verifiable with contracts promising $\hat{c}_1$ as the period 1 payment. However, with nonverifiable types, the banking allocation is not a unique equilibrium as shown below.

Proposition 3
For all possible realizations of α above $\alpha^o = (1 - t)/R(1 - t\hat{c}_1)$, a deposit contract paying $\hat{c}_1$ in period 1 and $\hat{c}_2(\alpha)$ in period 2 dominates autarky in the absence of a bank run.

For proof, note that if $\hat{c}_1$ is the period 1 payment then, from (7), the period 2 payment is $\hat{c}_2(\alpha) = \alpha R(1 - t\hat{c}_1)/(1 - t)$. If $\alpha > \alpha^o = (1 - t)/R(1 - t\hat{c}_1)$, then $\hat{c}_2 > 1$ and $\hat{c}_1 > 1$.

While a contract promising $\hat{c}_1$ in period 1 and $\hat{c}_2(\alpha)$ in period 2 can implement an allocation that dominates autarky in the absence of a run, such a contract implements a fundamental bank run equilibrium whenever depositors calculate, upon receipt of information that reveals the α realization, that the dominant type 2 strategy is early withdrawal. Since $\hat{c}_2$ depends on α, early withdrawal dominates deposit retention for type 2 depositors for any α such that $\hat{c}_2 < \hat{c}_1$.

Proposition 4
There exists a critical value $\alpha^r = (1 - t)\hat{c}_1/R(1 - t\hat{c}_1) > \alpha^o$, such that $\hat{c}_2 < \hat{c}_1$ for all $\alpha < \alpha^r$. A fundamental run will arise when the realized value of α is below α^r.

Proof follows directly from solving (7) for the value α^r that equates $\hat{c}_2$ with $\hat{c}_1$. Notice that for $\alpha \in [\alpha^o, \alpha^r)$, the allocation implemented by the deposit contract would dominate the autarky allocation in the absence of a run but, since $\hat{c}_2 < \hat{c}_1$, a fundamental run will occur. Suspension of period 1 payments at t will not eliminate fundamental runs. Even if period 1 payments are suspended for $\alpha < \alpha^r$, it remains that $\hat{c}_2 < \hat{c}_1$ gives rise to a fundamental run.

[8]We assume that $\alpha R > 1$ for ease of exposition and to highlight the role of the bank in providing liquidity to type 1 agents. It is not essential, however, that $\alpha R > 1$.

The bank can, however, eliminate a fundamental run with a deposit contract that allows for restriction of early payments.

Proposition 5
By restricting period 1 payments for realizations of $\alpha < \alpha^r$, the bank can eliminate a fundamental run. Especially when $\alpha \in [\alpha^o, \alpha^r)$, the deposit contract with restricted payments implements as a unique Nash equilibium an allocation that dominates the autarky allocation.

For the fundamental bank run range of $\alpha < \alpha^r$, the return disturbance is unfavorable, but not so low that greater returns are realized from liquidating investments in period 1 than from holding investments.[9] The bank restricts period 1 payments after a fraction $\bar{f}$ of depositors have been paid $\hat{c}_1$ when information reveals that $\alpha < \alpha^r$. Restricted payments c_2^r are chosen in period 1 to solve

$$\max_{c_1^r} \frac{1}{1 - \bar{f}} [(t - \bar{f})u(c_1) + (1 - t)u(c_2)]$$

$$\text{subject to} \quad c_2^r = \frac{\alpha R(1 - t\hat{c}_1) + t\hat{c}_1 - (f - \bar{f})c_1^r - \bar{f}\hat{c}_1}{1 - f}$$

$$c_1^r \leq c_2^r.$$

The solution is easily verified to be $c_1^r = c_2^r = \dfrac{\alpha R(1 - t\hat{c}_1) + (t - \bar{f})\hat{c}_1}{1 - \bar{f}}$. Further, for the range of $\alpha \in [\alpha^o, \alpha^r)$, $1 < c_1^r = c_2^r$ and the deposit contract therefore implements an allocation that dominates autarky.

Restricted payments provide positive consumption to all depositors while a contract offering $\hat{c}_1$ in period 1 with suspension at t involves a risk of some type 1 depositors receiving nothing in period 1. Even with suspension, if restricted payments are not allowed it remains that $\hat{c}_2 < \hat{c}_1$ gives rise to fundamental runs for $\alpha < \alpha^r$.

Our analysis of restricted payments as a defense against fundamental runs is interesting in light of past financial crises in which banks restricted, rather than suspended, deposit payments (Sprague 1910, pp. 66, 182, 287). Sprague's discussion of the panic of 1893, for example, points out that "Suspension was at no time complete..." (Sprague 1910, p. 182). During actual periods of restricted pay-

---

[9] If the realized value of α satisfies $\alpha < \dfrac{1 - \epsilon}{R}$, then the bank realizes greater returns by liquidating investments in period 1. We have considered cases with $\alpha R > 1$ so $\alpha < \dfrac{1 - \epsilon}{R}$ does not arise in our discussion.

ments, banks used forms of payment discrimination based on information about depositors' liquidity needs, e.g. maximum per depositor withdrawals except for employers who were granted additional funds to meet payrolls (Sprague 1910, pp. 74, 287, 290). Such information was limited, however, given that incentives such as currency premiums (Sprague 1910, p. 187) existed for misrepresenting actual liquidity needs during crises.

Incentives for depositors to participate in a fundamental run arise from their calculation that early withdrawal is the dominant type 2 strategy given new information about investment returns. Thus, the model implies that fundamental runs and payment restrictions are events that should occur when new information reveals unfavorable investment return innovations. This implication is consistent with what Gorton (1984) refers to as the "Recession Hypothesis" according to which banking panics occurred as features of major business cycle downturns. Gorton's examination of the relationship between panics and a measure of liabilities of failed businesses in the National Banking Era provides empirical support for our explanation of incentives for depositors to run based on investment return information. Interpreting Gorton's liability measure as information received by depositors concerning future bank investment returns, his finding that a panic occurred when a critical level of the measure was attained supports the idea that information revealing unfavorable return innovations provides incentives for depositors to run.

Our analysis also provides insights into currency premiums during periods of financial crisis. Note that the size of restricted payments and, hence, the magnitude of the discount below contractually promised payments depends positively on the size of the return realization, α, and negatively on the fraction of depositors who have withdrawn prior to receipt of interim information, $\bar{f}$. Thus, restricted payments will be smaller and, hence, the depreciation of deposit claims in terms of the good will be larger the smaller is the return realization, α, and the larger the withdrawal volume prior to receiving information revealing unfavorable returns.[10] If we interpret the deposited good in the model as currency an implication is that during early stages of a business contraction, when returns are

---

[10]Friedman and Schwartz (1963, p. 110), writing about experiences of 1893, note that a currency permium is "...equivalent to a depreciation of the deposit dollar in terms of gold or foreign exchange...." In practice, the goods withdrawn from banks are dollars which are traded for ultimate consumption or other goods of currency.

revealed to be low enough for banks to restrict payments, the higher the ratio of currency to nontendered deposit claims and the lower the ratio of reserves to deposits, the larger will be deposit–claim depreciation.

V. Conclusion

We have analyzed deposit contracts when a bank faces the possibility of bank runs. The bank in our model can prevent a speculative bank run equilibrium, which arises whenever depositors believe that the number of deposit withdrawals will force the bank into insolvency, by designing a deposit contract that allows for suspension of payments when the number of withdrawals threatens to become too numerous. A contract that allows for suspension, however, does not eliminate incentives for depositors to participate in fundamental runs which arise when depositors calculate, given new information about investment returns, that deposit withdrawal dominates deposit retention. The bank can eliminate incentives to participate in a fundamental run by restricting payments when investment returns are unfavorable. The depreciation of deposit claims under payment restriction depends on the bank's portfolio return and the volume of withdrawals prior to the receipt of information revealing unfavorable returns.

References

Diamond, D. "Financial Intermediation and Delegated Monitoring," *Review of Economic Studies* 51 (No. 3 1984): 393-414.
Diamond, D., and Dybvig, P. "Bank Runs, Deposit Insurance, and Liquidity," *Journal of Political Economy* 91 (No. 3 1983): 401-19.
Engineer, M. "Bank Runs and the Suspension of Deposit Convertibility," *Journal of Monetary Economics* (1989): 443-54.
Freeman, S. "Banking as the Provision of Liquidity," *Journal of Business* (1988): 45-64.
Friedman, M., and Schwartz, A. J. *A Monetary History of the United States.* Princeton: Princeton University Press, 1963.
Gorton, G. "Banking Panics and Business Cycles," Working Paper, University of Pennsylvania, August 1984.
_____. "Bank Suspension of Convertibility," *Journal of Monetary Economics* (March 1985): 177-93.
Postlewaite, A., and Vives, X. "Bank Runs as an Equilibrium Phenomenon," *Journal of Political Economy* (1987): 485-91.

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

Townsend, R. "Optimal Contracts and Competitive Markets with Costly State Verification" *Journal of Economic Theory* (1979): 265–93.

Waldo, D. "Bank Runs, the Deposit-Currency Ratio, and the Interest Rate," *Journal of Monetary Economics* (May 1985): 269–77.

Wallace, N. "Another Attempt to Explain an Illiquid Banking System: The Diamond and Dybvig Model with Sequential Service Taken Seriously," Federal Reserve Bank of Minneapolis, *Quarterly Review* (Fall 1988): 3–16.

Williamson, S. "Costly Monitoring, Financial Intermediation and Equilibrium Credit Rationing," *Journal of Monetary Economics* 18 (1986): 159–80.