BEBR

**FACULTY WORKING
PAPER NO. 89-1593**

Liquidity Preference, Costly State
Verification and Optimal Financial
Intermediation

A. P. Villamil

College of Commerce and Business Administration
Bureau of Economic and Business Research
University of Illinois Urbana-Champaign

BEBR

Liquidity Preference, Costly State Verification, and
Optimal Financial Intermediation

A. P. Villamil

Department of Economics

Abstract

This paper establishes that an optimal contract, combining features of the well-known Diamond and Dybvig (1983) and Townsend (1979, 1988) models, resembles banking. The contract and the associated allocations are derived from a social planner's problem which contains the Diamond and Dybvig and Townsend models as sub-problems. The analysis accomplishes the following: it unites the liquidity preference and cost minimization literatures in a simple way; resolves the demand deposit/demand equity problem in the Diamond and Dybvig model; introduces a notion of efficient bankruptcies into the liquidity preference literature; and poses the government regulation vs. laissez faire banking debate as a callability problem.

In this paper I present a model of banking that combines elements from two of the constructs often used to study the financial intermediation process. The first construct is the Diamond and Dybvig (1983) model of banking with a continuum of depositors who are each subject to a privately observed preference shock.[1] The second construct is the Townsend (1979, 1988) costly state verification model in which at least one agent has a random endowment, the realization of which can be made public only at a cost.[2]

My model maintains some features from the Diamond and Dybvig model (i.e., the three period setting, depositors who are subject to a privately observed preference shock, and a single, nonstorable constant returns to scale technology). However, it differs from theirs in the following ways. I assume that the technology has a certain one-period return and a random two-period return, and that the depositors are endowed with an input to this technology but do not observe its random outcome. I also introduce a second type of agent (the entrepreneur), who has sole access to the production technology but has no endowment of the input. As in the Townsend model, the entrepreneur privately observes the random output from the technology, and must incure a cost to publicly reveal the realization (to the depositors).

Two main results are obtained from this analysis.

First, the model provides a rationale for the emergence of demand deposits rather than demand equities. In particular, Jacklin (1987) has noted that in the Diamond and Dybvig model with no aggregate uncertainty about preferences, the ex ante optimal consumption allocations can be implemented by equity trading schemes. Jacklin's analysis

is important because it opens the Diamond and Dybvig model to the Fama (1980) critique, which questions the specialness of banks. This paper shows that the Townsend (1979, 1988) costly state verification analysis, which uses private information on ex post payoffs to rationalize fixed commitment debt contracts, can be used to resolve this demand deposit/demand equity indeterminancy problem.[3]

The argument is as follows. When there is private information about entrepreneurs' project returns which is costly to verify, an intermediary (i.e., a coalition of all depositors) will have an incentive to minimize verification costs by writing contracts that call for fixed (non-contingent) payments in some states of nature and contingent payments in others. The non-contingent payments (indexed for liquidity preference) correspond directly to the demand deposits in the Diamond and Dybvig analysis.[4] However the contingent payments, which represent costly but optimal bankruptcies by the entrepreneurs (and hence the intermediary), have no analogue in their analysis. Thus, in addition to resolving the demand deposit/demand equity problem, my model introduces an alternative notion of (optimal) bankruptcy into the Diamond and Dybvig model.

Second, my model provides some insight into the two constituent constructs on which it is based--the liquidity preference and cost minimization theories of financial intermediation--and the need for government regulation. In particular, my model contains the Diamond and Dybvig model (with no aggregate uncertainty and suspension of convertibility) and the Townsend model as special cases, and gives rise to an optimal contract of the following form. During the

planning period an entrepreneur invests in his/her production tech-
nology and commits to: (i) withdraw amount λ from the technology at
time 1, paying the intermediary a pre-specified, fixed rate of return;
and (ii) withdraw the remaining $1-\lambda$ at time 2, paying the intermediary
a pre-specified, fixed rate of return (if the realization from the
technology is sufficient to cover the promised payment) or calling for
costly state verification and making a liquidation payment (if the
realization is not sufficient to cover the promised payment).   Thus,
in this economy the intermediary simply transfers what it receives
from entrepreneurs to the depositors, and this intermediation process
results in an optimal allocation of resources.

My model provides some insights into its constituent models be-
cause the contractual arrangement that I study is effectively an
alternative interpretation of the suspension of convertibility policy
proposed by Diamond and Dybvig to eliminate inefficient bankruptcies.
The contract is of particular interest, however, because it appears to
be considerably simpler than what is observed both in practice and in
the literature.   Thus, it raises the question--why doesn't this
arrangement arise?   More specifically, why in practice do inter-
mediaries tend to call in loans (e.g., during the Great Depression)
when there is a simple, efficient contractual arrangement under which
it is optimal not to?   This is another way to ask the perennial
question: Can markets, left to their own accord, achieve an optimal
allocation of resources without government intervention, or are exist-
ing models of the financial intermediation process still incomplete in
important ways?

The debate in the literature regarding this problem (i.e., government regulation vs. private (laissez-faire) banking arrangements) appears to be dichotomized by two alternative positions. Have loans been called in, as Friedman and Schwartz (1963) suggest, owing to some poorly specified disruption in the intermediation process? Or, is it government policy itself, as Gorton and Haubrich (1987) suggest, which restricts the ability of intermediaries to write optimal contracts? It is hoped that posing the question in terms of loan callability may suggest some strategies for future work which will be useful in resolving this debate. The specifics of this discussion, however, will be deferred until the concluding section.

The paper is organized as follows. In Section I, I specify the structure of the economy. In Section II, I consider the case of a single entrepreneur, while in Section III I consider the case of finitely many entrepreneurs. Finally, in Section IV I make some concluding remarks.

I. The Environment

As in the Diamond and Dybvig model, I consider a three period economy with a planning period and two subsequent consumption periods indexed by t=0, 1, 2. The economy is populated by two different types of agents: a continuum of ex ante identical Diamond and Dybvig-type "depositors" described by the zero unit interval (i.e., [0,1]), and J ex ante identical Townsend-type "entrepreneurs" indexed by j=1, ..., J. All agents maximize expected utility, and will be characterized by their respective preferences, endowments, access to a technology, and information.

All depositors are ex ante identical, but may have different ex post, as of t=1, utility functions over the consumption of a single good in periods 1 and 2. Let $u_\theta(c_1, c_2)$, denote these ex post depositor preferences, where c_t is consumption at date t and θ is a random variable which is privately observed by each individual depositor at the beginning of time 1. Let θ take on one of two values in the set $\{1,2\} \equiv X$, and Π_i denote the probability that $\theta = i \epsilon X$ with $\Pi_1 + \Pi_2 = 1$. Assume both X and (Π_1, Π_2) are known by all agents at time 0 and that Π_i is the fraction of depositors who realize $\theta = i$. This assumption corresponds to the version of the Diamond and Dybvig model with no aggregate uncertainty. Further assume that $u_\theta(\cdot) = U(c_1) + \beta_\theta c_2$, with $U'(c_1) > 0$, $U''(c_1) < 0$, and $\beta_2 > \beta_1 = 0$. It follows from this specification of utility that depositors are risk averse with respect to first period consumption, risk neutral with respect to second period consumption, and that $\theta = 1$ indicates an impatient depositor (i.e., one who values first period consumption relative to second period consumption more highly than a $\theta = 2$ depositor).

All entrepreneurs are ex ante identical with respect to each other, but have utility functions over the consumption of the single good in periods 1 and 2 that are different from the depositors' utility functions. Let $u(c_1, c_2) = V(c_1) + W(c_2)$ denote the entrepreneurs' preferences, where V and W are strictly concave, increasing, twice continuously differentiable, and $W'(0) = \infty$ and $W'(\infty) = 0$. It follows from this specification of utility that entrepreneurs are risk averse with respect to both first and second period consumption.

Depositors and entrepreneurs have the following endowments and technologies in this economy. Each depositor is endowed with one unit of the t=0 good. Each entrepreneur is endowed with a technology of the following form: (x_0, x_1, x_2) is in the technology set if (x_0, x_1, x_2) = $[-x, \lambda x, (1-\lambda)xy]$, for some $x > 0$ and some $\lambda \epsilon [0,1]$. This common technology displays constant returns to scale, and $-x$ indicates the input of t=0 good, λx indicates the amount of t=1 good withdrawn from the project at return 1, and $(1-\lambda)x$ indicates the amount of t=2 good withdrawn at return y.

Let the entrepreneur's second period return, y, be a random variable with a finite support. In particular, let $y = a_k$ for $k = 1, \ldots, K$, $a_{k+1} > a_k > 0$ for all k, and $E[y] > 1$ (where $E[\cdot]$ denotes an expectation operator). Finally, let the outcomes for y be drawn independently across the J entrepreneurs. As in Townsend (1979, 1988), assume that each entrepreneur privately observes the outcome from his/her project at t=2, but has at his/her disposal a costly state verification technology that can be used to publicly reveal the realization of y to all other agents.[5] The cost of using this verification technology (i.e., publicly revealing y) is μ units of time 2 good and will be further specified in the analysis that follows.

I will complete the model by specifying the following assumptions about the nature of the asymmetric information and the verification technology:

A.1:   All agents have the same symmetric information conditions at

     time 0.

A.2:   The verification procedure is deterministic.

A.3:   If verification of a particular entrepreneur's realization of y

     occurs, then the realization is made known to all agents without

     error.

A.4:   If an entrepreneur is indifferent between requesting and not

     requesting verification, he/she requests verification.

A.5:   There is ex post enforcement of all agreements.

    Assumptions A.1, A.2, A.3, and A.5 correspond directly to the

assumptions in the Townsend (1979, 1988) costly state verification

model.[6] However, assumption A.4, which resolves any indeterminacy

regarding when verification will occur, is stated somewhat differently

than in Townsend. He assumes (1979, p. 268) that if an entrepreneur

is indifferent between verifying and not verifying the outcome of y,

he/she does not request costly state verification. My statement of

this assumption requires a straightforward amendment to some of

Townsend's arguments, but will be useful in the analysis that follows.[7]

II.   The Model with a Single Entrepreneur (J=1)

    In this section I will describe a contract and then state a social

planner's problem involving the choice of the components of the con-

tract. As is quite standard, the planning problem will involve the

maximization of a weighted average of the agents' utilities subject to

truth telling constraints (which ensure that agents correctly reveal their asymmetrically observed private information) and aggregate resource constraints on the consumption of time 1 and time 2 good. I assume that the planner is restricted to choose only symmetric allocations and is subject to the same informational conditions as individual agents (i.e., the planner knows the distribution of types and the technology at t=0). By symmetric, I mean that all depositors receive the same ex ante allocation at time 0. Consistent with the restriction to symmetric allocations, I will let $c_{ti}(y)$ denote the consumption of time t good by each type i depositor and $c_t(y)$ denote the consumption of time t good by the single entrepreneur.

Now following and extending Townsend, consider the following contractual arrangement. At t=0, a coalition of all depositors, henceforth called the intermediary, and the entrepreneur write the following kind of contract. Let g_1 denote the actual transfer of time 1 good from the entrepreneur to the intermediary and $\bar{g}_1$ denote the pre-state contractual choice of g_1. Similarly, let $g_2(y)$ denote the actual post-state transfer of time 2 good from the entrepreneur to the intermediary as a function of y and $\bar{g}_2(y)$ denote the pre-state contractual choice of the function g_2. Finally, let S denote the values of y for which verification will occur, S' denote the values for which verification will not occur, and $\bar{S}$ and $\bar{S}'$ denote the respective pre-state contractual choices of these sets. Thus, a contract $[\bar{g}_1, \bar{g}_2(y), \bar{S}]$ is a pre-state specification, contingent on y at t=2, of the amount of consumption good to be transferred in each period and of when there is to be verification.

As in Townsend (1979, p. 269), subsequent to the realization of y, the entrepreneur announces whether there is or is not to be verification. If verification occurs, specified amounts of time 2 good are forfeited by the entrepreneur, y is revealed to all agents, and the entrepreneur transfers what was agreed upon. If verification does not occur, then the entrepreneur may transfer any amount consistent with the prior specification for the no verification state.

Following Townsend (1979, 1988) I will restrict my analysis to the class of consistent contracts, where a contract $[\bar{g}_1, \bar{g}_2(y), \bar{S}]$ is said to be <u>consistent</u> if

(2.1) $g_1 = \bar{g}_1$;

(2.2) $g_2(y) = \bar{g}_2(y)$ for all y; and

(2.3) $S = \bar{S}$.

Equations (2.1), (2.2), and (2.3) correspond to consistency conditions (i) and (ii) in Townsend (1979, p. 270).

Townsend (1979, p. 270) establishes that a contract $[\bar{g}_1, \bar{g}_2(y), \bar{S}]$ is consistent if and only if:

(2.4) $g_2(y) = \bar{g}_2$ for $y \epsilon \bar{S}'$; and

(2.5) $\bar{g}_2(y) + \mu \leq \bar{g}_2$ for $y \epsilon S$, where $\bar{g}_2$ is some constant.

Townsend (1979) notes that condition (2.4) is obvious as "under a consistent contract the agreed-upon transfer cannot depend on information which is known only to [one] agent," and proves that it and equation

(2.5) are necessary and sufficient in Lemma 2.1, p. 287. Note that no condition to ensure that $g_1 = \bar{g}_1$ is necessary since $\bar{g}_1$ is not contingent. In Lemma 2.2, Townsend (1979, p. 270) establishes that restricting the analysis to the set of consistent contracts is without loss of generality. Hence as in Townsend, in what follows I will only talk about g_1, $g_2(y)$, and S, and will impose consistency conditions (2.4) and (2.5) on (g_2, S) directly.

Finally, following Townsend I assume that the verification cost is a continuously differentiable, convex function of the contingent transfer (i.e., $\mu[g_2(y)]$). Townsend interprets this cost as an auditing expense, and notes that it follows from this specification that large insolvencies are more expensive than small ones.[8]

I can now state a social planner's problem for an economy with a continuum of depositors and a single entrepreneur. Let I(y) be an indicator function with I(y) = 0 indicating that verification does not occur (i.e., y∈S') and I(y) = 1 indicating that verification does occur (i.e., y∈S). Finally, let E[·] denote the expectation with respect to the distribution of y.

<u>Problem 2.1</u>: Choose λ, $(g_1, g_2(y), I(y))$, $c_{ti}(y)$, $c_t(y)$, for t=1, 2 and i=1, 2 to maximize $E[u\{c_1, c_2(y)\}]$

subject to: $E[\Sigma_i \Pi_i u_i\{c_{1i}, c_{2i}(y)\}] \geq D$,

(2.6a) $\quad g_2(y) = \bar{g}_2$ for I(y) = 0;

(2.6b) $\quad \bar{g}_2(y) + \mu \leq \bar{g}_2$ for I(y) = 1;

(2.7) $E[u_\theta\{c_{1\theta},c_{2\theta}(y)\}] \geq E[u_\theta\{c_{1\theta'},c_{2\theta'}(y)\}]$ for $\theta,\theta'\epsilon X$;

(2.8a) $\Pi_1 c_{11} + \Pi_2 c_{12} \leq g_1$;

(2.8b) $g_1 + c_1 \leq \lambda$;

(2.9) $\Pi_1 c_{21} + \Pi_2 c_{22} \leq g_2$ for $I(y) = 0$;

(2.9b) $g_2 + c_2(y) \leq [1-\lambda]y$ for $I(y) = 0$;

(2.10a) $\Pi_1 c_{21}(y) + \Pi_2 c_{22}(y) \leq g_2(y)$ for $I(y) = 1$; and

(2.10b) $g_2(y) + c_2(y) \leq [1-\lambda]y - \mu$ for $I(y) = 1$.

The first constraint states that the depositors' utility must be
at least D.[9] Equations (2.6a) and (2.6b) restate consistency con-
ditions (2.4) and (2.5) for the two alternative verification states.
Equation (2.7) is an incentive compatibility constraint on depositors
which states that the utility that a depositor receives from truth-
fully revealing his/her type (i.e., requesting the payoffs associated
with θ) is at least as great as the utility that the depositor receives
from misrepresenting his/her type (i.e., requesting the payoffs asso-
ciated with $\theta' \neq \theta$).

The remaining constraints are resource constraints on the alloca-
tion of time 1 and time 2 good on the intermediary and all agents,
respectively. Constraint (2.8a) is a resource constraint on the divi-
sion of the time 1 transfer by the intermediary between the depositor
types. Constraint (2.8b) is a resource constraint on the aggregate
consumption of time 1 good by all agents (i.e., the depositors and the

entrepreneur). Constraints (2.9a) and (2.10a) are resource constraints on the division of the time 2 transfer by the intermediary between the depositor types in the no verification and verification states, respectively. Finally, constraints (2.9b) and (2.10b) are resource constraints on the aggregate consumption of time 2 good by all agents in the two verification states.

Characterization of the Solution

Since the objective is continuous and the constraint set is compact, a solution to Problem 2.1 exists. However, in order to describe some aspects of the solution, it is helpful to analyze Problem 2.1 in stages. In particular, in order to be able to appeal to Townsend's results that characterize $g_2(y)$ and S, I state the following (time 2) problem and show: (a) the time 2 problem is identical to a problem considered by Townsend, and (b) any solution to Problem 2.1 is a solution to the time 2 problem.

Let $C_2(y) = \Sigma_i \Pi_i c_{2i}(y)$ denote the total second period consumption by depositors. Working backwards, consider the following (time 2) problem:

Problem 2.1b: For any λ, K, g_1, c_1, c_{11}, c_{12}, choose $c_2(y)$, $C_2(y)$, $g_2(y)$, $I(y)$ to

maximize $E[u\{c_1, c_2(y)\}]$

subject to: $E[C_2(y)] \geq K$, and (2.6a), (2.6b), (2.9a), (2.9b), (2.10a), and (2.10b).

Problem 2.1b is identical to Problem 3.1 in Townsend (1979, p. 272).

In Proposition 3.1, Townsend (1979, p. 273) establishes that when
$\mu[g_2(y)]$ is a continuously differentiable, convex function of the con-
tingent transfer, as I have assumed, the following results hold.
First, the verification interval is comprised of two sets, given by
$S = \{y:y \leq y^*\}$ and $S' = \{y:y>y^*\}$. This result, stated as Proposition
3.1, indicates that verification occurs for outcomes of y which are
less than some critical value and verification does not occur for
outcomes of y which are above this value.[10] Second, the verification
interval is nontrivial. This result, established by example, states
that the verification region need not be either empty or the entire
interval. Thus, it follows from Proposition 2.1b that bankruptcy by
the entrepreneur (and hence the intermediary) occurs in some but not
all states of nature.

I now establish:

Proposition 2.1: Any solution to Problem 2.1 is a solution to Problem
2.1b.

Proof: Denote by tildes "~" a solution to Problem 2.1 and let $\tilde{C}_2(y) =$
$\Pi_1 \tilde{c}_{21}(y) + \Pi_2 \tilde{c}_{22}(y)$. Suppose by way of contradiction that $[\tilde{C}_2(y), \tilde{c}_2(y)]$
is not a solution to Problem 2.1b for $\lambda = \tilde{\lambda}$ and $K = E[\tilde{C}_2(y)] = \tilde{K}$.
Moreover, let $[\hat{C}(y), \hat{c}_2(y)]$ be a solution to Problem 2.1b for $\lambda = \tilde{\lambda}$
and $K = \tilde{K}$. I show that "~" cannot be a solution to Problem 2.1 by
showing that an alternative solution is feasible for Problem 2.1 and
is Pareto superior to the "~" solution. The alternative is $\tilde{\lambda}$, $\tilde{c}_1$,
$\tilde{c}_{11}$, $\tilde{c}_{12}$, $\hat{c}_2(y)$ and $\hat{c}_{22}(y)$ satisfying $\Pi_2 \hat{c}_{22}(y) = \hat{C}_2(y)$ and $\hat{c}_{21}(y) = 0$.

First, since $[c_{21}(y), c_{22}(y)]$ appear in ex ante depositor utility only by way of $E[\Pi_2 c_{22}(y)]$ and since $E[\Pi_2 c_{22}(y)] \leq E[C_2(y)]$, it follows that this alternative is Pareto superior to the "~" solution. As regards feasibility, since the "~" solution satisfies the t=1 resource constraint and since the t=2 resource constraints are part of Problem 2.1b, the alternative solution satisfies all of the resource constraints. As regards the consistency constraints, the alternative solution satisfies the constraints for the entrepreneur as they are part of Problem 2.1b. All that remains to be shown is that $[\hat{c}_{21}(y),$ $\hat{c}_{22}(y)]$ and $[\tilde{c}_{11}, \tilde{c}_{12}]$ satisfy the consistency constraint for the depositors (i.e., inequality (2.7)).

Let $\hat{w}_i = E[\hat{c}_{2i}(y)]$ and $\tilde{w}_i = E[\tilde{c}_{2i}(y)]$, for i=1,2. To satisfy the depositors' consistency constraint, $[\hat{c}_{21}(y), \hat{c}_{22}(y)]$ must be chosen so that:

(2.10a) $\quad U_1(\tilde{c}_{11}) \geq U_1(\tilde{c}_{12})$, and

(2.10b) $\quad U_2(\tilde{c}_{12}) + \beta_2 \hat{w}_2 \geq U_2(\tilde{c}_{11}) + \beta_2 \hat{w}_1.$

By consistency of the "~" solution, (2.10a) holds and

(2.11) $\quad U_2(\tilde{c}_{12}) + \beta_2 \tilde{w}_2 \geq U_2(\tilde{c}_{11}) + \beta_2 \tilde{w}_1.$

However, since $\hat{w}_1 = 0$ and $E[\hat{C}_2(y)] \geq E[\bar{C}_2(y)]$, $\hat{w}_1 \leq \tilde{w}_1$ and $\hat{w}_2 > \tilde{w}_2$. Hence, (2.11) implies (2.10b). ∎

Problem 2.1b yields optimal consumption allocations of the form $c_2(y) = f(\lambda,K;y)$, $C_2(y) = h(\lambda,K;y)$, a transfer function $g_2(y) = g_2^*(\lambda,K;y)$ and an indicator function $I(y) = I^*(\lambda,K;y)$. Continuing to work backwards, the time 1 problem can be written:

Problem 2.1a: Choose λ, K, g_1, c_1, c_{11}, c_{12}, $c_{21}(y)$, $c_{22}(y)$ to

maximize $E[u\{c_1,f(\cdot)\}]$

subject to: $E[\Sigma_i \Pi_i u_i\{c_{1i},c_{2i}(y)\}] \geq U$, (2.7), (2.8a), (2.8b), and

$$h(\lambda,K;y) = \Sigma_i \Pi_i c_{2i}(y).$$

I now show that Problem 2.1a can be further simplified.

Proposition 2.2: Any solution to Problem 2.1a has $c_{21}(y) = 0$.

Proof: Suppose by way of contradiction that there exists a solution to Problem 2.1a which does not satisfy $c_{21}(y) = 0$. Denote this solution by $\tilde{\lambda}$, $\tilde{c}_1$, $\tilde{c}_{11}$, $\tilde{c}_{12}$, $\tilde{c}_{21}$, $\tilde{c}_{22}$, $\tilde{K}$, with $\tilde{c}_{21} > 0$. I show that "~" cannot be a solution to Problem 2.1a by showing that for λ, K, c_1, c_{11}, c_{12}, $h(\cdot)$, $f(\cdot)$ fixed at the "~" solution, when $\tilde{c}_{21} > 0$ I can construct an alternative allocation $[\hat{c}_{21}, \hat{c}_{22}]$, with $\Pi_1\hat{c}_{21}(y) + \Pi_2\hat{c}_{22}(y) = \hat{C}(y) = \tilde{h}(\cdot)$, but $\hat{c}_{21}(y) < \tilde{c}_{21}(y)$ and $\hat{c}_{22}(y) > \tilde{c}_{22}(y)$. This alternative allocation satisfies the resource and consistency constraints from Problem 2.1a but increases the utility of depositors without decreasing the utility of the entrepreneur.

The resource constraints at t=1 and t=2 remain satisfied since only the division of c_{21} and c_{22} is changed in the proposal and all else, including $\tilde{h}(\cdot)$, remains fixed. The consistency constraints are

also satisfied as the constraints on the entrepreneur, and the constraint on type 1 depositors, $U_1(\tilde{c}_{11}) \geq U_1(\tilde{c}_{12})$ are unchanged in the proposal. The constraint on type 2 depositors, $U_2(\tilde{c}_{12}) + E[\hat{c}_{22}(y)] \geq U_2(\tilde{c}_{11}) + E[\hat{c}_{21}(y)]$, is satisfied as well since $E[\hat{c}_{22}(y)] > E[\tilde{c}_{22}(y)]$ and $E[\hat{c}_{21}(y)] < E[\tilde{c}_{21}(y)]$ by construction and the "$\sim$" solution is consistent. Finally, this proposal does not affect the utility of depositors since $E[\hat{c}_{22}(y)] > E[\tilde{c}_{22}(y)]$ and $c_{21}(y)$ is not an argument of ex ante depositor utility.

‖

It follows from Proposition 2.2 that Problem 2.1a can now be restated as follows:

<u>Problem 2.1a'</u>: Choose λ, K, g_1, c_1, c_{11}, c_{12} to

maximize $E[u\{c_1, f(\cdot)\}]$

subject to: $E[\Sigma_i \Pi_i u_i \{c_{1i}, h(\cdot)\}] \geq U$

(2.7) $E[u_\theta \{c_{1\theta}, c_{2\theta}\}] \geq E[u_\theta \{c_{1\theta'}, c_{2\theta'}\}]$ for $\theta, \theta' \varepsilon X$;

(2.8a) $\Pi_1 c_{11} + \Pi_2 c_{12} \leq g_1$;

(2.8b) $g_1 + c_1 \leq \lambda$;

Problem 2.1a' is identical to Problem 2.1a except that it follows from Proposition 2.2 that $c_{21}(y) = 0$ and $c_{22}(y) = C_2(y)$, so that the division of the aggregate t=2 transfer of consumption good to the depositors is already determined.

The solution to Problem 2.1a' (i.e., the stage 1 problem) is of particular economic interest because it resembles the Diamond and Dybvig model with no aggregate uncertainty (i.e., (Π_1, Π_2) known). In

their analysis, as in my model, agents cannot achieve the optimal (full-information) allocation by competitive markets owing to non-verifiable private information about depositors' types. Diamond and Dybvig argue that the demand deposit contract, which accommodates depositors' private information, is an alternative allocation mechanism that can be used to achieve an optimal allocation. This argument applies directly to my analysis as well.

However, Diamond and Dybvig (1983, p. 402) also claim that the demand deposit contract which they propose "has an undesirable equilibrium (a bank run)" associated with it, and propose a policy--namely, suspension of convertibility--which can be used to eliminate the run.[11] It is important to note that runs arise in the Diamond and Dybvig model because depositors fear (for some conjectures about cohorts' behavior) that all investment will be completely liquidated at t=1, and consequently their promised two-period returns will not be available. The Diamond and Dybvig suspension policy eliminates the run problem by assuring all depositors that some amount of t=2 good will indeed be available. My model also displays this feature, but differs from the Diamond and Dybvig analysis in that suspension of convertibility is effectively embedded into the contract mechanism.

In particular, in my model the entrepreneur produces λ amount of t=1 good at the first stage (irrespective of ex post depositor behavior), leaves the remainder (i.e., $[1-\lambda]$) in production until the second stage, and the intermediary simply honors the withdrawal requests it receives from depositors (subject to its resource constraints). Thus as under the Diamond and Dybvig suspension policy,

since depositors are certain that investment will not be completely

liquidated at the first stage (under the contract that I propose),

speculative runs do not arise. However, bankruptcies do occur (in

some states of nature), but as in Townsend, they are consistent with

an optimal allocation of resources.

III. The Generalized Model

In this section I extend the model with a continuum of depositors

and a single entrepreneur to one with a continuum of depositors and

finitely many entrepreneurs. Following Townsend, I begin by consider-

ing two symmetric, ex ante identical entrepreneurs. For simplicity I

assume that the intermediary evenly divides all t=0 good between the

two ex ante identical entrepreneurs. Agents' preferences, endowments,

access to the technologies, and information are the same as in

Section I.

Again following and extending Townsend, consider the following

contractual arrangement which resembles banking. At t=0 the inter-

mediary, a coalition of all depositors, and each entrepreneur write a

contract, and the two entrepreneurs write a contract. I define these

agreements as follows: Let g_1^{ij} denote the actual post-state transfer

of time 1 good from entrepreneur j to the intermediary and $\bar{g}_1^{ij}$ denote

the pre-state contractual choice of g_1.[12] Let $g_2^{Aj}(y_1,y_2)$, for A=i,j'

and j=1,2, denote the actual post-state transfer of time 2 good, con-

tingent on the returns from both entrepreneurs, from entrepreneur j to

agent A (i.e., the intermediary or the entrepreneur), and $\bar{g}_2^{Aj}(y_1,y_2)$

denote the pre-state contractual choice of this function. Finally,

let S_j denote the set of realizations of y_j for which verification
will occur, S_j' denote the set of realizations for which verification
will not occur, and let $\bar{S}_j$ and $\bar{S}_j'$ denote their respective pre-state
contractual choices. Thus, a contract $[\bar{g}_1^{ij}, \bar{g}_2^{Aj}(y_1, y_2), \bar{S}_j]$ for A=i,j'
and j=1,2, is a pre-state specification, contingent on y_1 and y_2 at
t=2, of the amount of consumption good to be transferred in each
period and of when there is to be verification.

Subsequent to the realization of y_j, each entrepreneur announces
whether there is or is not to be verification. If verification
occurs, y_j is revealed to all agents and $\phi_j(y_j)$ units of time 2 good
are forfeited to nature. If both agents are verified, they transfer
what was agreed upon (i.e., $g_2^{Aj}(y_1, y_2) = \bar{g}_2^{Aj}(y_1, y_2)$ for $(y_1, y_2) \epsilon \bar{S}_1 x \bar{S}_2$).
If entrepreneur j verifies but j' does not, the entrepreneurs transfer
an amount consistent with: (i) a known value of y_j, and (ii) $y_{j'}$ in
the agreed upon nonverification region (i.e., $g_2^{Aj}(y_1, y_2) = \bar{g}_2^{Aj}(y_j)$ for
$(y_1, y_2) \epsilon S_j x (\bar{S}_{j'})'$). Finally, if neither agent verifies, they transfer
an amount consistent with the prior specification for the no verifica-
tion states (i.e., $g_2^{Aj}(y_1, y_2) = \bar{g}_2^{Aj}$ for $(y_1, y_2) \epsilon ((\bar{S}_j)' x (\bar{S}_{j'})')$).

Townsend (1979, p. 280) restricts his analysis to the class of
consistent contracts where, as in Section II, a contract $[\bar{g}_1^{ij}, \bar{g}_2^{Aj}, \bar{S}_j]$
for A=i,j' and j=1,2 is said to be <u>consistent</u> if:

(3.1) $g_1^{ij} = \bar{g}_1^{ij}$;

(3.2) $g_2^{Aj} = \bar{g}_2^{Aj}$;

(3.3) $S_j = \bar{S}_j$.

These equations are analogous to consistency conditions (2.1), (2.2), and (2.3) in Section II.

In Lemma 5.1, Townsend (1979, p. 280) establishes that conditions of the following form ensure that a bilateral contract is consistent.[13] A contract $[\bar{g}_1^{ij}, \bar{g}_2^{Aj}, \bar{S}_j]$, for A=1,j' and j=1,2, is consistent if and only if:

(3.4) $\qquad g_2^{Aj}(y_1, y_2) = \bar{g}_2^{Aj}$ for $(y_1, y_2) \varepsilon \bar{S}_1, x\bar{S}_2,;$

(3.5) $\qquad g_2^{Aj}(y_1, y_2) = \bar{g}_2^{Aj}(y_j)$ for $(y_1, y_2) \varepsilon \bar{S}_j x(\bar{S}_j,)';$

(3.6a) $\qquad \bar{g}_2^{Aj}(y_1, y_2) - \phi_j(y_j) \le \bar{g}_2^{Aj'}(y_j,)$ for $(y_1, y_2) \varepsilon \bar{S}_1 x\bar{S}_2;$ and

(3.6b) $\qquad \bar{g}_2^{Aj}(y_j) - \phi_j(y_j) \le \bar{g}_2^{Aj}$ for $y_j \varepsilon \bar{S}_j.$

As before, these conditions will be imposed directly and hence I will only talk about $[g_1, g_2(y), S]$ in what follows.

Let $I(y_j)$ be an indicator function with $I(y_j) = 0$ indicating that verification does not occur (i.e., $y_j \varepsilon S_j'$) and $I(y_j) = 1$ indicating that verification does occur (i.e., $y_j \varepsilon S_j$). I can now state a planning problem for an economy with a continuum of depositors and two entrepreneurs.

<u>Problem 3.1</u>: Choose λ_j, $(g_1^{ij}, g_2^{Aj}(y_1, y_2), I(y_j))$, $c_{ti}(y)$, $c_t^j(y)$ for i=1,2, t=1,2, A=i,j', and j=1,2 to:

maximize $\Sigma_j \alpha_j E[u_j\{c_1, c_2^j(y)\}]$

subject to: $E[\Sigma_i \Pi_i u_i\{c_{1i}, c_{2i}(y)\}] \ge D;$

(3.4) $\qquad g_2^{Aj}(y_1,y_2) = g_2^{Aj}$ for $I(y_1) = I(y_2) = 0;$

(3.5) $\qquad g_2^{Aj}(y_1,y_2) = g_2^{Aj}(y_j)$ for $I(y_j) = 1$ and $I(y_{j'}) = 0;$

(3.6a) $\qquad g_2^{Aj}(y_1,y_2) - \phi_j[y_j] \leq g_2^{Aj'}(y_{j'})$ for $I(y_1) = I(y_2) = 1;$

(3.6b) $\qquad g_2^{Aj}(y_j) - \phi_j(y_j) \leq g_2^{Aj}$ for $I(y_j) = 1;$

(3.7) $\qquad E[u_\theta\{c_{1\theta}, c_{2\theta}(y)\}] \geq E[u_\theta\{c_{1\theta'}, c_{2\theta'}(y_2)\}]$

(3.8a) $\qquad \Pi_1 c_{11} + \Pi c_{12} \leq \Sigma_j g_1^{ij} \equiv C_1;$

(3.8b) $\qquad c_1^j \leq \lambda_j - g_1^{ij};$

(3.8c) $\qquad C_1 + \Sigma_j c_1^j \leq \Sigma_j \lambda_j;$

(3.9a) $\qquad \Pi_1 c_{21} + \Pi_2 c_{22} \leq \Sigma_j g_2^{ij} \equiv C_2$ for $I(y_1) = I(y_2) = 0;$

(3.9b) $\qquad c_2^j(y_j) \leq [1-\lambda_j]y_j - g_2^{ij} - g_2^{j'j} + g_2^{jj'}$ for $I(y_1) = I(y_2) = 0;$

(3.9c) $\qquad C_2 + \Sigma_j c_2^j(y_j) \leq \Sigma_j [1-\lambda_j]y_j$ for $I(y_1) = I(y_2) = 0;$

(3.10a) $\qquad \Pi_1 c_{21}(y_j) + \Pi_2 c_{22}(y_j) \leq g_2^{ij}(y_j) + g_2^{ij'} \equiv C_2^i(y_j)$ for

$\qquad\qquad I(y_j) = 1$ and $I(y_{j'}) = 0;$

(3.10b) $\qquad c_2^j(y_j) \leq [1-\lambda_j]y_j - g_2^{ij}(y_j) - g_2^{j'j}(y_j) + g_2^{jj'} - \phi_j[y_j]$ for

$\qquad\qquad I(y_j) = 1$ and $I(y_{j'}) = 0;$

(3.10c) $\qquad c_2^{j'}(y_1,y_2) \leq [1-\lambda_j]y_{j'} - g_2^{ij'}(y_j) - g_2^{jj'}(y_j) + g_2^{jj'}$ for

$\qquad\qquad I(y_j) = 1$ and $I(y_{j'}) = 0;$

(3.10d) $\qquad C_2(y_j) + c_2^j(y_j) + c_2^{j'}(y_1,y_2) \leq \Sigma_j [1-\lambda_j]y_j - \phi_j[y_j]$ for

$\qquad\qquad I(y_j) = 1$ and $I(y_{j'}) = 0;$

(3.11a) $\Pi_1 c_{21}(y_1, y_2) + \Pi_2 c_{22}(y_1, y_2) \leq \Sigma_j g_2^{ij}(y_1, y_2) \equiv c_2^i(y_1, y_2)$

for $I(y_j) = I(y_2) = 1;$

(3.11b) $c_2^j(y_1, y_2) \leq [1-\lambda_j]y_j - g_2^{ij}(y_1, y_2) - g_2^{j'j}(y_1, y_2)$

$+ g_2^{jj'}(y_1, y_2) - \phi_j[y_j]$ for $I(y_1) = I(y_2) = 1;$ and

(3.11c) $C_2(y_1, y_2) + c_2^j(y_1, y_2) \leq \Sigma_j[1-\lambda_j]y_j - \Sigma_j\phi_j[y_j]$ for $I(y_1)$

$= I(y_2) = 1.$

Problem 3.1 is identical to Problem 2.1 except that the objective

function is now a weighted average of the two entrepreneurs' utilities

(where the weights $\Sigma_j \alpha_j = 1$ and $\alpha_j \geq 0$ are exogenously given), and the

resource constraints are defined over the joint verification regions.

The objective is continuous and the constraint set is compact, hence a

solution exists.

As in Section II, Problem 3.1 can be decomposed into stages. Using

Townsend's assumptions about the verification cost and restrictions on

exchange, the stage 2 problem is identical to his Problem 5.1. Since

it can be shown that any solution to Problem 3.1 must satisfy the time

2 problem, the results established by Townsend apply directly. Fur-

ther, the stage 1 component corresponds to the Diamond and Dybvig

model. Hence the results from their analysis apply as well. As in

Townsend, this analysis can be further extended to the case of

finitely many entrepreneurs.

IV. Concluding Remarks

This paper establishes that an optimal contract, combining
features of the well known Diamond and Dybvig and Townsend models,
resembles banking. The contract and the associated allocations are
derived from a social planner's problem. Features of the contract
are described by decomposing the overall planner's problem into two
sub-problems. This decomposition allows me to appeal directly to
results established by Diamond and Dybvig (1983) and Townsend (1979,
1988).

The analysis accomplishes the following. First, it unites the
liquidity preference and cost minimization literatures in a simple
way. Second, it resolves the demand deposit/demand equity indeter-
minancy problem in the Diamond and Dybvig model (with the precise
nature of the solution depending on the specification of agents'
preferences, the verification technology, and the distribution func-
tion--see Townsend (1988) for a discussion and some simulations).
Third, it introduces a notion of efficient bankruptcies into the
liquidity preference literature.[14] Finally, the analysis poses the
government regulation vs. laizze-faire banking debate as a callability
problem, and suggests that its resolution may lie along two lines: a
deeper understanding of the theoretical rationalizations of call-
ability, and a careful analysis of the historical evidence on legal
restrictions which prohibit banks from writing optimal contracts.

Footnotes

[1]Liquidity risk in this context is the risk that too many agents will wish to withdraw in a given time period and the intermediary will not have enough assets on hand to meet this demand. I consider the version of the Diamond and Dybvig model with no aggregate uncertainty about the preference shock, hence all agents know the total number of withdrawals in each time period if depositors correctly reveal their type. This specification of the economy (i.e., no aggregate uncertainty and truthful revelation of type) is equivalent to the standard informational restriction that the principle knows the distribution of agent types in the economy, but does not know the identity of any particular agent (e.g., see Villamil (1988)).

[2]The Diamond and Dybvig and the Townsend models are seminal contributions to two main branches of the financial intermediation literature: liquidity preference models and cost minimization models of financial intermediation. For example, the following papers incorporate aspects of the Diamond and Dybvig model: Bernanke and Gertler (1985), Haubrich and King (1984), and Smith (1984); while papers which incorporate aspects of the Townsend model are: Boyd and Prescott (1986), Diamond (1984), Gale and Hellwig (1985), and Williamson (1987). For a more extensive discussion of the literature, and an excellent report on the historical development of the study of financial intermediaries, the reader is referred to Gertler (1988).

[3]A recent alternative to the costly state verification analysis (on which much of the cost minimization view of financial intermediation is based) is the costly state falsification model of Lacker and Weinberg (1989). However, the contracts which emerge in their environment resemble "equity" instruments (vs. debt) most closely.

[4]In this paper (as in Diamond and Dybvig), demand deposits allow agents to diversify their liquidity risk. However, see Calomiris and Kahn (1988) for an alternative explanation of demandable debt.

[5]The apparent asymmetry in agents' access to a verification technology in my model stems from the fact that there is no aggregate uncertainty associated with the preference shock (hence there is no need to verify), but there is aggregate uncertainty associated with the investment technology. However, an alternative rationalization of the absence of preference shock verification, which would preclude its use even in the presence of aggregate uncertainty, is that it is infinitely costly to ascertain this information.

[6]Mookherjee and Png (1987) study the Townsend (1979) model with a stochastic verification technology. They note that the choice of a stochastic or deterministic technology (i.e., assumption A.2) can change the nature of the optimal contracts under certain circumstances, but that assumption A.3 (i.e., perfect verification) is not

restrictive as the results from the model can be extended for small errors by continuity arguments.

[7] In particular, Townsend (1979, p. 270, Lemma 2.1) states a necessary and sufficient condition for truthful revelation by an entrepreneur with a strict inequality as he assumes that if the entrepreneur is indifferent between verifying and not verifying the outcome of y he/she does not request costly state verification. However, the analogous (consistency) constraint in my model will be stated with a weak inequality owing to assumption A.4. It is important to note that Townsend's proof of Lemma 2.1 remains valid under this assumption.

[8] Townsend refers to the situation where $\mu[\cdot]$ is a continuously differentiable, convex function of the transfer function as the "classical case." Although he also establishes results for the "nonclassical case," in which μ is equal to a constant, those results depend on additional assumptions.

[9] D, an exogenous constant, is effectively a weight on depositors' utility (predetermined by the planner or by some earlier bargaining process).

[10] Proposition 3.1 specifies S* with a strong inequality. However, I specify S* with a weak inequality owing to the difference between my assumption A.4 and the corresponding assumption used by Townsend. This amendment does not change the nature of the result.

[11] Postlewaite and Vives (1987) provide an alternative example in which there is a unique equilibrium with a positive probability of a bank run. They further argue that when the selection between the good and the bad outcomes in the Diamond and Dybvig analysis is modeled as a game with incomplete information, then bank contracts cannot necessarily achieve the optimal allocation in the Diamond and Dybvig model (nor in their model).

[12] Note that the entrepreneurs do not exchange time 1 good as it is not contingent.

[13] Lemma 5.1 in Townsend (1979, p. 280) is stated with strict inequalities. Equations (3.6a) and (3.6b) are stated with weak inequalities in my analysis owing to my statement of assumption A.4.

[14] Introducing a notion of efficient bankruptcies (vs. inefficient speculative runs) into the liquidity preference literature defines two points of a continuum of possibilities. The most interesting cases are likely to be those which lie between the two extremes, as models which contain both types of bankruptcies (and where it is possible to distinguish between them) are necessary before economists can offer sensible policy advice. In that sense, this paper is very much in the spirit of Chari and Jagannathan (1988) and Jacklin and Bhattacharya (1988).
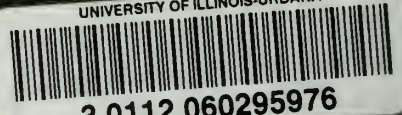
References

Bernanke, B. and Gertler, M. (1985), "Banking in General Equilibrium,"
    NBER Working Paper No. 1647.

Boyd, J. and Prescott, E. C. (1986), "Financial Intermediary
    Coalitions," Journal of Economic Theory, 38, 211-32.

Bryant, J. (1980), "A Model of Reserves, Bank Runs, and Deposit
    Insurance," Journal of Banking and Finance, 4, 335-344.

Calomiris, C. and Kahn, C. (1988), "The Role of Demandable Debt in
    Structuring Optimal Banking Arrangements," University of Illinois,
    mimeo.

Chari, V. V. and Jagannathan, R. (1988), "Banking Panics, Information
    and Rational Expectations Equilibrium," Journal of Finance, 43:3,
    749-760.

Diamond, D. (1984), "Financial Intermedation and Delegated
    Monitoring," Review of Economic Studies, 51, 393-414.

Diamond, D. and Dybvig, D. (1983), "Bank Runs, Deposit Insurance, and
    Liquidity," Journal of Political Economy, 91:3, 401-419.

Fama, E. (1980), "Banking in the Theory of Finance," Journal of Mone-
    tary Economics, 6, 39-57.

Friedman, M. and Schwartz, A. (1963), A Monetary History of the United
    States: 1867-1960, Princeton, Princeton University Press.

Gale, D. and Hellwig, M. (1985), "Incentive-Compatible Debt Contracts
    I: The One-Period Problem," Review of Economic Studies, 52,
    647-64.

Gertler, M. (1988), "Financial Structure and Aggregate Economic
    Activity: An Overview," Journal of Money, Credit and Banking,
    20:3, 559-587.

Gorton, G. (1987), "Check Clearing, Banking Panics, and the Structure
    of the Banking Industry," mimeo.

Gorton, G. and Haubrich, J. (1987), "Bank Deregulation, Credit Markets
    and the Control of Capital," Bubbles and Other Essays, Carnegie-
    Rochester Series on Public Policy, Vol. 26, K. Brunner and A.
    Meltzer, eds., Amsterdam: North Holland, pp. 289-334.

Haubrich, J. and King, R. (1984), "Banking and Insurance," NBER
    Working Paper No. 1312.

Jacklin, C. (1987), "Demand Deposits, Trading Restrictions, and Risk Sharing," <u>Contractual Arrangements for Intertemporal Trade</u>, E. Prescott and N. Wallace, ed. Minnesota Studies in Macroeconomics, vol. 1, Minneapolis University of Minnesota Press.

Jacklin, C. and Bhattacharya, S. (1988), "Distinguishing Panics and Information-based Bank Runs: Welfare and Policy Implications," <u>Journal of Political Economy</u>, 96:5, 568-592.

Lacker, J. and Weinberg, J. (1989), "Optimal Contracts Under Costly State Falsification," Purdue University, mimeo.

Mookherjee, D. and Png, I. (1987), "Optimal Auditing, Insurance and Redistribution," UCLA Graduate School of Management, unpublished manuscript (April).

Postlewaite, A. and Vives, X. (1987), "Bank Runs as an Equilibrium Phenomenon," <u>Journal of Political Economy</u>, 95:3, 485-491.

Smith, B. (1984), "Private Information, Deposit Interest Rates, and the 'Stability' of the Banking System," <u>Journal of Monetary Economics</u>, 14:3, 293-318.

Townsend, R. (1979), "Optimal Contracts and Competitive Markets with Costly State Verification," <u>Journal of Economic Theory</u>, 21:2, 265-293.

Townsend, R. (1988), "Private Information and Limited Insurance: Explaining Consumption Anomalies," <u>Journal of Monetary Economics</u>, 21:2/3, 411-450.

Villamil, A. (1988), "Price Discriminating Monetary Policy: A Non-uniform Pricing Approach," <u>Journal of Public Economics</u>, 35, 385-392.

Williamson, S. (1987), "Costly Monitoring, Optimal Contracts, and Equilibrium Credit Rationing," <u>Quarterly Journal of Economics</u>, 102, 135-45.