Federal Reserve Bank
of Minneapolis

Fall 1988

Quarterly Review

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Vol. 12, No. 4 ISSN 0271-5287

This publication primarily presents economic research aimed at improving policymaking by the Federal Reserve System and other governmental authorities.

Produced in the Research Department. Edited by Preston J. Miller, Kathleen S. Rolfe, and Inga Velde. Graphic design by Terri Desormey, Public Affairs Department.

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Another Attempt to Explain an Illiquid Banking System: The Diamond and Dybvig Model With Sequential Service Taken Seriously

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A pervasive feature of banking system portfolios is that they are illiquid: short-term obligations cannot be met unless a sufficient amount are renewed or rolled over. For two centuries, solutions have been proposed and policies implemented to try to solve the problems that seem to accompany such illiquidity. Among proposed solutions are Adam Smith's ([1789] 1937, bk. 2, chap. 2) advice to bankers to avoid illiquidity by matching the maturities of assets and liabilities and Milton Friedman's (1960) suggestion that banks offering demand deposits be subject to 100 percent reserve requirements. In the United States, among the policies that have been implemented are fractional reserve requirements, the Federal Reserve System as a purported lender of last resort, and the federal deposit insurance systems.

Still, despite the long concern about banking system illiquidity, only very recently has anyone provided anything close to a coherent explanation of illiquid banking system portfolios. In 1983, Douglas Diamond and Philip Dybvig offered a model of banking that does provide the ingredients of an explanation. They also claimed to have discovered a policy that resembles deposit insurance, is consistent with their explanation, and prevents any problems from accompanying the existence of illiquid banking system portfolios. Their analysis, however, suffers from one important flaw, which I attempt to correct.

That flaw concerns one of the main ingredients of the Diamond and Dybvig model: the *sequential service constraint,* the requirement that a bank must service its customers sequentially, on a first-come, first-served basis. This requirement is crucial because without it, as shown below, the model does not explain banking system illiquidity. Although Diamond and Dybvig seemed aware of the importance of the sequential service constraint, they were vague about why it arises, what in the environment forces banks to deal with their customers sequentially instead of, for example, being able to cumulate withdrawal requests and make payments contingent on the total. Diamond and Dybvig (p. 408) offered hints about such an environment when they said that imposing the sequential service constraint allows them to "capture the flavor of continuous time (in which depositors deposit and withdraw at different random times) in a discrete model." However, they did not appeal to these hints when they asserted consistency between the sequential service constraint and the policy that they identify with deposit insurance and that overcomes the difficulties associated with illiquid banking system portfolios: Diamond and Dybvig (p. 414) said only that "the realistic sequential-service constraint represents some services that a bank provides but which we do not explicitly model."

The model I present here builds on Diamond and Dybvig's hints and is an environment in which people are isolated from each other but are in contact with their bank in a way that implies the sequential service constraint. (This is what I mean by *taking sequential service seriously.*) Although my model is in other respects the same as theirs, mine has two quite different implications. One is infeasibility of the policy which Diamond and Dybvig called *deposit insurance* and which in their model overcomes all the difficulties associated with illiquid banking system portfolios; the policy is inconsistent with the explanation of the sequential service constraint. The other distinguishing implication is that, in some versions of my model, desirable banking arrangements have the property that the returns that people realize on their deposits depend on the (random) order in which they withdraw.

The implication concerning deposit insurance is important because deposit insurance is a controversial policy. Although many people recognize that deposit insurance produces undesirable incentives for banks to take on risky portfolios, most think that the benefits of deposit insurance outweigh the costs implied by those risk-taking incentives. The benefits, though, have never been carefully described within a model that explains illiquid bank portfolios. It is, therefore, important to determine whether, as they claimed, Diamond and Dybvig succeeded in describing those benefits. I argue that they did not.

The implication concerning returns being dependent on the order in which people withdraw is important because such dependence resembles historically observed bank suspensions in which those who withdrew after banks suspended payments were able to trade their deposits only at a discount. Furthermore, people's negative view of such dependence, particularly before the creation of the Federal Reserve System, has significantly influenced policy. The model set out here suggests that this negative view may be unjustified.

While these two implications highlight the difference between my model and Diamond and Dybvig's, our models share other implications concerning long-standing disputes about policy toward banking. These common implications follow from the Diamond and Dybvig explanation of banking system illiquidity. For example, as suggested above, some economists, most notably Smith and Friedman, have not considered illiquidity to be a necessary concomitant of banking. Others have taken the view that the basic function of banks is to lend long and borrow short—hence, to take on illiquidity. Both my model and Diamond and Dybvig's defend the latter view. Both models imply that attempting to force banks to be liquid is synonymous with preventing banks from carrying out their main function.

To help readers understand Diamond and Dybvig's explanation of an illiquid banking system and my explanation of the sequential service constraint, I describe my model twice. First I describe the model in a more-or-less nontechnical way and summarize its results. Although some of the results that distinguish my model from Diamond and Dybvig's cannot be fully described in this context, the main ingredients of our models can. A more complete and necessarily more technical description of my model and results follows. This requires previous exposure to economic theory at the level of a rigorous intermediate microeconomic theory course and to calculus.

A Camping Trip Economy

The Diamond and Dybvig model has three main ingredients. One is that individuals are uncertain about when they will want to make expenditures. This uncertainty produces a demand for assets which, loosely speaking, have good returns even if they are held for a short time. Another main ingredient is what underlies the sequential service constraint, namely, that spending by different people occurs successively. Thus, if people are holding assets that resemble demand deposits at banks, the withdrawal demands of different people must be dealt with separately, one after the other. The third main ingredient is that real investment projects are very costly to restart if they are interrupted.

These ingredients are not new. The first has long been viewed as producing a demand for what have been called *liquid assets*. The second is a standard ingredient of analyses that treat a bank's reserve management problem as an inventory problem. The third is a plausible feature of most investment projects. What is new in the Diamond and Dybvig presentation is the attempt to embed versions of these ingredients in a model of an entire economy in a way that permits at least some of their consequences for the desirability of various policies to be deduced rigorously. The following description of a camping trip shows how this can be done.

A Problem

Suppose a group of people, N in number, on the last evening of their camping trip, are planning two subsequent meals—a late-night snack and breakfast, breakfast being the last meal before their return home. In the evening, each member of the group has available y units of food which I shall treat as a single uniform and divisible object. This food will grow if stored: Each unit will become R_1 units if held until a late-night snack and will become R_1R_2 units if held until breakfast, R_1 and R_2 being fixed technological returns on physical investment. Note, however, that storage cannot begin at night. Any food taken out of storage then is either eaten or wasted. This is how the costliness of interrupting real investment projects is put into the model.

Uncertainty about the desired timing of expenditures appears here in the following way. All the campers know in the evening that they will each awaken sometime in the night and either will be hungry and will prefer to eat then (and skip breakfast) or will not be hungry and will prefer to wait until breakfast to eat. In the evening, all the campers have an idea of the probability that they will themselves be hungry during the night. Note that, in the evening, the individuals care about both contingencies: how much they will be able to eat during the night if they turn out to be hungry then and how much they will be able to eat at breakfast if they turn out to prefer to eat then.[1] Also, in the evening, people have at least a rough idea about the fraction of the group that will be hungry during the night.

Before I describe the ingredient that produces sequential service, I can indicate the potential gains from joint action which, if undertaken, will be the model's analogue of intermediation (organized as a mutual). This is most easily done if I assume, for the moment, that α_1 is each person's subjective probability that she or he will wake up hungry during the night and is also known by all in the evening to be the fraction of the group that will wake up hungry during the night. The probability of the alternative happening is α_2, which is $1-\alpha_1$. In order to describe the potential gains from joint action, I contrast what can potentially be achieved jointly with what individuals can achieve if they each act on their own, autarkically.

Acting alone, each person can look forward to a late-night snack of R_1y (if the person wakes up hungry) or a breakfast of R_1R_2y (if the person wakes up not hungry during the night). It is convenient to represent the magnitude of the late-night snack if hungry at night by c_1^1 and the magnitude of breakfast if not hungry at night by c_2^2. [The subscript denotes the *time* of the meal (1 for *night,* 2 for *morning*), and the superscript denotes the person's *state* during the night (1 for *hungry,* 2 for *not hungry*).] Thus, autarky achieves $c_1^1 = R_1y$ and $c_2^2 = R_1R_2y$ or, more succinctly, $(c_1^1, c_2^2) = (R_1y, R_1R_2y)$. Note that if each person acts alone in that way, then (since the fraction who wake up hungry is α_1), the total amount of food consumed during the night is α_1NR_1y. The key to understanding the potential for joint action is to note that if all the campers pool their resources in the evening, then they can conceivably arrange to have either more or less than α_1NR_1y consumed during the night.

To see how much more or less, let C_1 be the total amount consumed during the night and C_2 the total amount consumed at breakfast. Then the maximum C_2 consistent with a given C_1 is

$$(1) \qquad C_2 = R_2(NR_1y - C_1)$$

where the difference in parentheses is what is left to accumulate at the rate R_2 after all the late-night snacks, C_1, have been subtracted. Now, to compare these possibilities to autarky, suppose that the group can somehow arrange to have C_1 divided equally among the α_1N people who wake up hungry in the night and to have C_2 divided equally among the α_2N who wake up not hungry. Then $c_1^1 = C_1/\alpha_1N$ and $c_2^2 = C_2/\alpha_2N$. Substituting the implied expressions for C_1 and C_2 into equation (1) implies that the maximum c_2^2 consistent with a given c_1^1 is

$$(2) \qquad c_2^2 = R_2(R_1y - \alpha_1c_1^1)/\alpha_2.$$

The (nonnegative) combinations (c_1^1, c_2^2) that satisfy (2) are shown in Figure 1. Note that the autarkic outcome is among these.

As already noted, in the evening individuals care about both c_1^1 and c_2^2 because they do not know whether they will be hungry during the night. Suppose that they are able to rank all combinations of c_1^1 and c_2^2 and, in particular, all those that satisfy equation (2). There is no reason to suppose that among all combinations satisfying (2), the autarkic combination is most preferred. I will suppose that it is not and that the most preferred combination satisfying (2) is below and to the right of the autarkic combination, a point like that labeled $(\tilde{c}_1^1, \tilde{c}_2^2)$ in Figure 1.

While we should now appreciate the potential for joint action in this setting, other aspects of the model put barriers in the way of achieving any combination of (c_1^1, c_2^2) that satisfies (2) or analogous combinations for the case in which the fraction of the group that will be hungry in the night is not known with certainty.

Suppose that the group cannot meet during the night—for example, to determine how many people claim to be hungry then and to decide on the magnitude of a late-night snack based on the number of those claims. Suppose, instead, that people are *isolated* from

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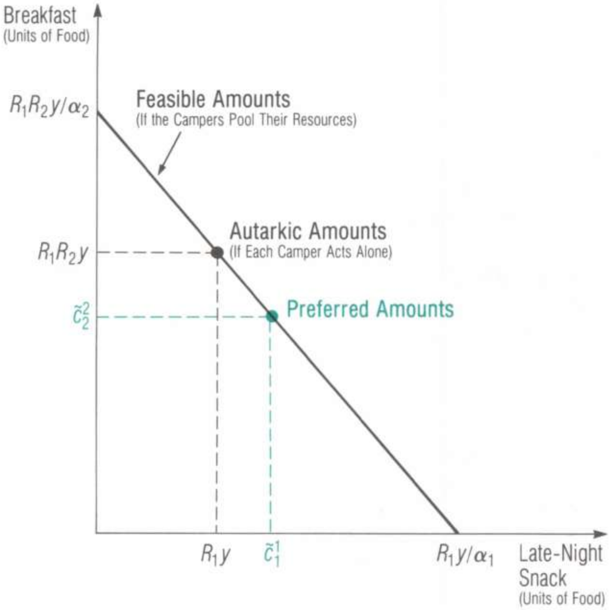
[1] This is analogous to situations in which individuals consider the purchase of insurance. For example, people think about how much fire insurance to buy because they care about their wealth both if a fire occurs in their house and if a fire does not occur.

Figure 1

**A Camper's Options:
Possible Late-Night Snacks and Breakfasts
Given the Resources and Technology**



each other, so that any arrangement must be consistent with people waking at a random time, not a time they choose, and not interacting with others during the night. This is the feature that implies the requirement that late-night withdrawal demands from any pooled resources be dealt with sequentially.

To help the group deal with this and with an assumed selfishness of individuals, suppose that the campers have at their disposal something like a cash machine. This machine, however, can be stocked with and dispense food, not cash. Moreover, food deposited in the machine in the evening grows in accord with the fixed technological returns, R_1 and R_2. The machine is centrally located, and each person contacts it once at a random time during the night. The machine has most of the capabilities and limitations of actual cash machines. Thus, it can check identities and prevent one person from making a withdrawal from another's account. It can also be programmed to cumulate withdrawals as they occur and to make subsequent withdrawals depend on earlier withdrawals. It cannot, however, determine whether a person is truly hungry during the night or is making a night withdrawal based on some other motive—for example, out of concern about whether the machine will run out of food and not be able to dispense the intended breakfasts.

Solutions

The problem facing the group in the evening in this camping trip economy is how to stock and program the machine, where this includes the possibility of not using it at all. Below, features of the solution to this problem will be described for two versions of the model. In one version, the fraction of people who will turn out to be hungry during the night is known in the evening; so I call this the version *without aggregate risk.* In the other version, *with aggregate risk,* there is uncertainty about that fraction. Here I will summarize both versions' solutions to the food machine problem, emphasizing what I think are close analogues between features of those solutions and features of intermediation in actual economies.

In both versions of the model, a solution will have each member of the group place some resources in the machine, which will be programmed to pay out something greater than R_1 per unit deposited for late-night snacks and, therefore, something less than R_1R_2 per unit deposited for breakfast.

The benefits people get from such deposits are analogous to the benefits people in actual economies get from holding liquid assets. The individual members of the group do not know whether they themselves will want to eat during the night or at breakfast. Each gives up some possible long-run return—is willing to have a breakfast smaller than R_1R_2y—for a larger possible short-run return—having a late-night snack larger than R_1y. This resembles the position of people who buy travelers' checks for a trip while being uncertain about how much they will spend during the trip. Such uncertainty means that they may end up returning with some of those checks, which then would have a lower return than alternative assets they could have purchased. However, that possible sacrifice was deemed worthwhile at the time of purchase because of the possibility that the travelers' checks would be spent, in which case the checks would have had a better return than alternative assets.

In the model, any such *liquidity* for individuals comes at the expense of *illiquidity* for the machine. Since in the evening people do not know whether they will be hungry during the night, the machine promises to pay out late-night snacks to whoever wants them. Since all have the option to withdraw, the machine's promises or obligations are entirely short term; they resemble demand deposits or savings accounts, deposits which give the depositor the option to withdraw at any time. If D is the total amount of food units deposited, the machine's total late-night obligation would be judged in the evening by an outsider (like a bank examiner) to exceed R_1D if it is programmed to pay out late-night snacks per unit deposited that exceed R_1. However, the machine's total late-night resources are only R_1D. Hence, in the most straightforward way of defining *illiquidity,* the machine has an illiquid portfolio.

Such illiquidity does not necessarily cause problems. It does if the machine is programmed simply to pay out late-night snacks to whoever asks for them as long as it can. Then the machine would have problems which resemble threatened bank runs. For consider those campers who wake up not hungry during the night. They each know that if all others who wake up not hungry attempt to withdraw, then the machine will run out and not be able to make any breakfast payments. Hence, even if they are not hungry, campers who think others not hungry will attempt to withdraw will themselves attempt to withdraw.

If there is no uncertainty about the fraction of the group who will turn out to be hungry in the night, then (as Diamond and Dybvig showed) there is a straightforward way to program the machine to avoid such crises of confidence: simply program the machine to shut down for the night after the total of late-night withdrawals reaches $\alpha_1 N\tilde{c}_1^1$. Since $(\tilde{c}_1^1, \tilde{c}_2^2)$ satisfies (2), this rule assures that the machine will have enough at breakfast to give the planned amount to each person who waits until then to withdraw. This shutdown scheme is like a threatened suspension of payments by banks.

If there is uncertainty about the fraction of the group who will turn out to be hungry in the night, then matters are considerably more complicated. Given such aggregate uncertainty, Diamond and Dybvig claimed that a policy they identified with deposit insurance was necessary and sufficient to produce desirable outcomes. However, as noted above and as I show below, that policy is not feasible if the isolation of individuals during the night is taken seriously as a restriction on what is feasible. I also show that having late-night payments depend on the random order in which individuals withdraw can be desirable.

The camping trip economy can also be used to analyze versions of policies, like the Smith and Friedman proposals, that limit the amount of illiquidity banks take on. In general, bank illiquidity can be limited by restricting bank assets, bank liabilities, or both. Since this model has only one possible asset, the only way to limit illiquidity here is to adjust the stream of promised payments on liabilities. In terms of Figure 1, the machine's portfolio can be made more liquid by changing the payment stream from the preferred point $(\tilde{c}_1^1, \tilde{c}_2^2)$ to something closer to $(R_1 y, R_1 R_2 y)$, the point of complete liquidity at which the machine could meet all its promises even if everyone tried to withdraw at night. However, any such limitation on illiquidity obviously comes at the expense of the well-being of depositors. Moreover, imposing complete liquidity makes the machine superfluous.

As you have no doubt noticed, the model in this paper omits many features of actual economies. The model contains only campers and the food machine. It does not contain, for example, anything that resembles separate financial and business sectors. Thus, the proper analogies to draw are between the campers of the model and consumers in actual economies and between the food machine of the model and the combined or consolidated financial and business sectors of actual economies. (After all, the machine holds as an asset a real investment, not loans to businesses that engage in real investment.) The result concerning illiquidity, then, is that the combined financial-business sector has an illiquid portfolio. Somewhat related to the absence of separate financial and business sectors is the absence of anything that resembles money. Also, the model has only one kind of real asset, so that the combined financial-business sector of the model, unlike that in actual economies, is not making any choices about the kinds of assets to hold.

These and other omissions can be viewed as the price we pay for being able to rigorously deduce the effect on people's well-being of policies like liquidity requirements, as was done above, using Figure 1. To put this more positively, the model suggests that three plausible conditions are enough to explain illiquid banking system portfolios:

- People's preferences make them want to have assets that can be cashed in at optional times and that have relatively high payments if cashed in early.
- People are sufficiently isolated from each other that their early withdrawal demands must be accommodated on a first-come, first-served basis.

- The real investment technology has an irreversibility, or goods-in-process, feature.

In other words, the model suggests that illiquid banking system portfolios can be understood without complications like separate financial and business sectors, money, and asset choices.

A Closer Look at the Model

Assumptions

Here I present a detailed description of the model in the form of a list of assumptions.

ASSUMPTION 1. *Time Periods and Goods*
The economy has three time periods, labeled $t=0$, $t=1$, and $t=2$, and one good per period.

Period 0 is when decisions about intermediation arrangements are made, decisions like whether to set up some kind of intermediation arrangement and, if so, what kind. Periods 1 and 2 are the periods for which there is uncertainty about desired expenditure patterns. In particular, at $t=0$ each individual is uncertain about whether she or he will want to consume at $t=1$ or $t=2$.

ASSUMPTION 2. *People and Endowments*
The economy has N people, and each person is endowed with y units of just the period 0 good.

Although people (and the economy) are endowed only with the period 0 good, a technology is available that permits goods to be produced at $t=1$ and $t=2$ using the period 0 good.

ASSUMPTION 3. *The Technology Set*
Everyone in the economy has access to the following technology set. Let a_t be an output (if negative, an input) of the period t good. The triplet (a_0, a_1, a_2) is in the economy's technology set if $(a_0, a_1, a_2) = (-a, \lambda R_1 a, (1-\lambda) R_1 R_2 a)$ for some $a>0$ and $\lambda \in [0,1]$.

Here a is the input of the period 0 good, R_1 the gross return between $t=0$ and $t=1$, R_2 that between $t=1$ and $t=2$, and λ the fraction of the input withdrawn at $t=1$.

There is an irreversibility, or goods-in-process, aspect of this technology. Period 2 goods are produced only by starting with period 0 goods as input. In particular, goods withdrawn at $t=1$ cannot be used to produce period 2 goods; once withdrawn, they must be consumed at $t=1$.

Now I describe preferences. To do this I let c_t^h denote the period t consumption of a person who turns out to be type h, where $h=1$ means *impatient* (to consume at $t=1$) and $h=2$ means *patient* (willing to wait to consume at $t=2$). At $t=0$, people do not know whether they will turn out to be type 1 or type 2. That being so, in general, they care about the 4-tuple c_t^h for $t=1,2$ and $h=1,2$, which will be denoted by c. Here is the specific way people care:

ASSUMPTION 4. *Preferences*
Everyone has identical preferences at $t=0$. Each maximizes the expected value of

$$U(c) \equiv \sum_{h=1}^{2} \alpha_h u^h(c_1^h, c_2^h)$$

where

(3) $u^h(c_1^h, c_2^h) = g(c_1^h + \delta_h c_2^h)$ and $0 < \delta_1 < 1/R_2 < \delta_2$

(4) $g' > 0$, $g'' < 0$, and $g'(R_1 y)/g'(\delta_2 R_1 R_2 y) > \delta_2 R_2$

(5) $\alpha_1 = 1 - \alpha_2$ and α_h is, in general, random: $\alpha_h = \alpha_h^k$ with probability p_k for $k = 1, 2, \ldots, K$.

These preferences may be interpreted as follows. At $t=0$, each person thinks she or he will turn out to be type h at $t=1$ with probability α_h. Being type h means having at $t=1$ the utility function over $t=1$ and $t=2$ consumption given by $u^h(c_1^h, c_2^h)$.

In Assumption 4, condition (3) says that these $t=1$ utility functions have straight-line indifference curves with slopes ordered as shown in Figure 2. This is the condition that implies, as we will see later, that desirable arrangements have $c_2^1 = 0$ (impatient people consuming only at $t=1$) and $c_1^2 = 0$ (patient people consuming only at $t=2$).

Condition (4) in Assumption 4 assures that when $c_2^1 = c_1^2 = 0$, the indifference, or level, curves of $U(c) = \alpha_1 g(c_1^1) + \alpha_2 g(\delta_2 c_2^2)$ are qualitatively as shown in Figure 3. In particular, it assures that a tangency between such indifference curves and the pairs satisfying (2) is to the right of the point $(R_1 y, R_1 R_2 y)$ and is above the line $\delta_2 c_2^2 = c_1^1$. To see this, note that at such a tangency, the slope of an indifference curve of $\alpha_1 g(c_1^1) + \alpha_2 g(\delta_2 c_2^2)$, $-\alpha_1 g'(c_1^1)/\alpha_2 \delta_2 g'(\delta_2 c_2^2)$, is equal to the slope of (2), $-\alpha_1 R_2/\alpha_2$. This equality can be written $g'(c_1^1)/g'(\delta_2 c_2^2) = \delta_2 R_2$. Since $\delta_2 R_2 > 1$ and $g'' < 0$ (marginal utility is diminishing), any such tangency satisfies $c_1^1 < \delta_2 c_2^2$ (is above the line $\delta_2 c_2^2 = c_1^1$ in Figure 3). Finally, the inequality $g'' < 0$ and the last inequality assumed in (4) imply that any such tangency satisfies $c_1^1 > R_1 y$ [is to the right of $(R_1 y, R_1 R_2 y)$ in

Figure 2
Indifference Curves of Patient and Impatient People at Period 1

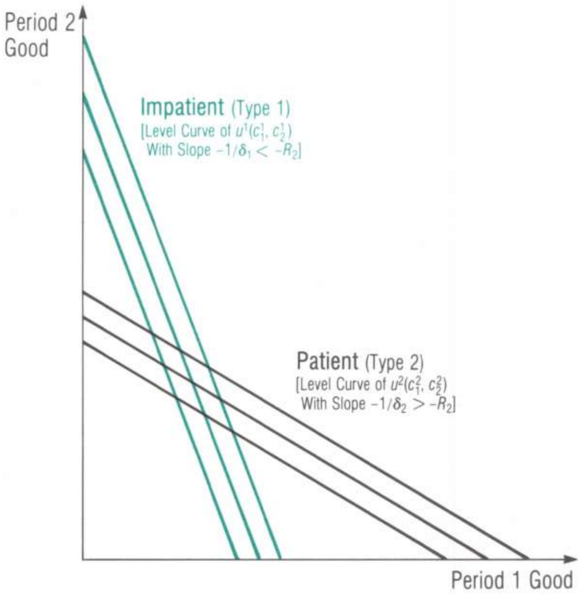


Figure 3]. As you can verify, all the assumptions about g are satisfied by $g(x) = -x^{-b}$ for $b > 0$, but not by $g(x) = x^{1/2}$ or by $g(x) = \ln x$.

The last condition of Assumption 4, (5), will be discussed below.

ASSUMPTION 5. *Private Information About Types*
Although people learn their own type at $t = 1$, no one else does. That is, a person's type is not public information.

This assumption rules out ordinary kinds of insurance arrangements in which payments are made dependent on publicly observable events. It lets people misrepresent themselves to the machine. Put differently, if people are to act in accord with their true type, then the alternatives offered by the machine must give them an incentive to do so; that is, these alternatives must be *incentive compatible.*

ASSUMPTION 6. *Aggregate Fraction of Types*
The fraction of the population who turn out to be type h at $t = 1$ is α_h.

Note that, according to Assumptions 4 and 6, the distribution of the fraction of the population who turn out to be type h is the same as the distribution of the probability for each person of turning out to be type h. In the version of this model without aggregate risk, the fraction and the probability are known [$K = 1$ in (5)]; in the version with aggregate risk, they are random ($K > 1$).

The above assumptions do not differ in a significant way from those set out by Diamond and Dybvig. The next two assumptions, however, are at best implicit in their presentation.

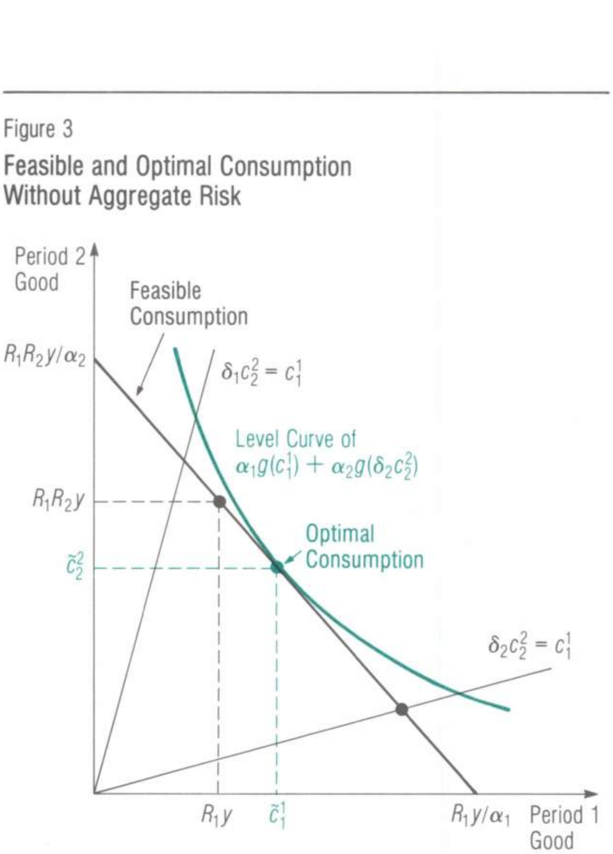
ASSUMPTION 7. *Isolation in Period 1*
During period 1, people are isolated from each other, although each contacts a central location at some instant during the period. The order in which they contact that location is random (and viewed by them as such) and uniformly distributed: the probability that a person is among the fraction v who first contact the central location is v. In contrast to period 1, at $t = 0$ and $t = 2$ people are all together.

Although this isolation assumption may seem extreme, it is consistent with the notion that people hold liquid assets because they may find themselves impatient to spend when they do not have access to asset markets, in which they can sell any asset at its usual market price. The assumption is also consistent with the notion that demand deposits provide the holder with the possibility of spending at any time, if not also at any place, a notion which implicitly assumes that not all people are together. Also, note that people are not choosing when to contact the machine. Each person contacts the machine at a random time, and the person's choice is limited to trying or not trying to make a withdrawal.

ASSUMPTION 8. *A Quasi-Cash Machine*
There is a machine into which the period 0 good can be deposited. The amount deposited grows according to the technology of Assumption 3, and withdrawals made at $t = 1$ cannot be reinvested. The machine is at the central location, so that people contact it once and at random times during period 1. The machine operates like a cash machine in that it is able to check a person's account to determine whether the person is entitled to make a withdrawal. And at $t = 0$ the machine can be programmed to compute functions of withdrawals as they occur and to make subsequent withdrawals depend on previous withdrawals. The machine cannot, however, determine (with a lie detector, for example) whether a person is patient or impatient.

Figure 3

Feasible and Optimal Consumption Without Aggregate Risk



Desirable Arrangements

Given those assumptions, the task now is to describe features of desirable intermediation arrangements for two versions of the model. As indicated above, an *intermediation arrangement* is a way of stocking and programming the machine. In addition to requiring that any such arrangement be consistent with Assumptions 1–8, I will only consider *symmetric* arrangements, those which treat everyone at time 0 the same. The *desirability* of arrangements that satisfy these conditions will be judged by the magnitude of expected utility, the expected value of $U(c)$, as described in Assumption 4. In other words, desirability is judged from the point of view of time 0.

To put this more formally, I will be describing features of the solution to two social planning problems. The objective for the problems is maximization of the expected value of $U(c)$. The constraints are symmetry and Assumptions 1–8. In one problem, the aggregate fraction of type 1 people is known; in the other, that fraction is random. The social planner should be viewed as having control of all the resources at $t = 0$, Ny units of the time 0 good, and access to the technology. The planner knows preferences as described in Assumption 4, but in the version with the fraction of types random, the planner knows its distribution, but must infer the realization. The content of Assumptions 7 and 8 is that the planner at $t = 1$ encounters people one by one, in a random order. The planner must determine a person's period 1 consumption when the person is encountered. The planner can make the individuals' period 1 consumption depend on what they say about themselves, on their type, and on what the planner has learned from the people already encountered. The planner cannot, however, first question everyone and then decide on each person's period 1 consumption.

□ *Without Aggregate Risk*

In the version of the model without aggregate risk, the fraction of each type of person is known ($K = 1$). An upper bound on the desirability of a symmetric arrangement is obtained by choosing a nonnegative 4-tuple c to maximize $U(c)$ as described in Assumption 4 subject to Assumptions 1–3 and 6. This is an upper bound because the other assumptions impose further restrictions that at best will not be binding. In fact, Diamond and Dybvig showed that they need not be binding.

I begin by describing the 4-tuple which produces this upper bound. I denote it by $\tilde{c}$. Symmetry and Assumptions 1–3 and 6 are equivalent as constraints to (1), $C_1 = \alpha_1Nc_1^1 + \alpha_2Nc_1^2$, and $C_2 = \alpha_1Nc_2^1 + \alpha_2Nc_2^2$. First note that $\tilde{c}$ satisfies $c_2^1 = c_1^2 = 0$. This follows from the form of u^1 and u^2 assumed in Assumption 4 and illustrated in Figure 2.[2] This, in turn, implies that $(\tilde{c}_1^1, \tilde{c}_2^2)$ satisfies equation (2) and $g'(c_1^1)/g'(\delta_2c_2^2) = \delta_2R_2$. Conditions (3) and (4) then imply that $\delta_2R_1R_2y > \delta_2\tilde{c}_2^2 > \tilde{c}_1^1 > R_1y$. That is, $(\tilde{c}_1^1, \tilde{c}_2^2)$ is as depicted in Figure 3.

Though they don't use my camping trip analogy, Diamond and Dybvig in effect described a way of stocking and programming the machine so that $\tilde{c}$ is achieved even though the restrictions given in the other assumptions apply. Their arrangement has everyone depositing their endowments in the machine. The machine is programmed to pay out exactly $\tilde{c}_1^1$ at $t = 1$, to whoever wants to withdraw during period 1, but only until those withdrawals total $\alpha_1N\tilde{c}_1^1$. At that point, the

[2]This is proved as follows. Let the 4-tuple c^* be feasible, but not such that $c_1^{*2} = c_2^{*1} = 0$. Then consider the following alternative: $c_1^1 = c_1^{*1} + c_2^{*1}/R_2$, $c_2^2 = c_2^{*2} + R_2c_1^{*2}$, $c_2^1 = c_1^2 = 0$. Feasibility of c^* implies feasibility of the alternative. And by (3) and $g' > 0$, the alternative gives a higher value of $U(c)$.

machine pays out no more; it suspends payments until $t = 2$, when, with everyone together, everything available is divided equally among those who did not withdraw during period 1.

To show that this *suspension arrangement* works, I will show that each person has an incentive under it not to misrepresent her or his type, no matter what the person thinks others will do. Let β be the fraction who withdraw at $t = 1$, where under the arrangement $0 \leq \beta \leq \alpha_1$. Then $R_2(R_1Ny - \beta N\tilde{c}_1^1)$ remains to be divided among $(1 - \beta)N$ people at $t = 2$. Therefore, each person gets $(R_1R_2y - \beta R_2\tilde{c}_1^1)/(1 - \beta)$. Since $\beta \leq \alpha_1$ (the suspension aspect of the arrangement), this amount is bounded below by $\tilde{c}_2^2$; and since $\tilde{c}_1^1 > R_1y$, it is bounded above by R_1R_2y. The upper bound implies that each type 1 person will attempt to withdraw at $t = 1$ because (3) implies that each prefers $\tilde{c}_1^1$ at $t = 1$ to R_1R_2y at $t = 2$. The lower bound and $\delta_2\tilde{c}_2^2 > \tilde{c}_1^1$ imply that no type 2 person will attempt to withdraw at $t = 1$ because each prefers $\tilde{c}_2^2$ at $t = 2$ to $\tilde{c}_1^1$ at $t = 1$.

The suspension aspect of the arrangement produces the lower bound. If, instead, the machine were programmed to pay out $\tilde{c}_1^1$ at $t = 1$ to whoever wants to withdraw, for as long as it can, then β could conceivably be so much greater than α_1 that a type 2 person, fearing that period 2 promised payments could not be met, would attempt to withdraw at $t = 1$. In other words, this alternative arrangement seems vulnerable to a type of *bank run*. However, in order to claim that bank runs would occur in this model under this alternative arrangement, we would have to append to the model subjective views held at $t = 0$ about the likelihood of a bank run that are consistent with the setting up of a joint arrangement being best even though the possibility of a bank run is anticipated. If a bank run is too likely, then the joint arrangement would not be set up.[3]

We can imagine the outcome of the above suspension arrangement emerging from a mutual or credit union organization in which depositors jointly determine the policy to be followed by the organization. People would be willing to join such an organization and deposit their endowments in it, because their alternative is using the technology on their own. That alternative, as described above, produces a worse outcome for the individuals than does the joint suspension arrangement.

We can also imagine the suspension arrangement outcome emerging from the operation of a bank that is not operated as a mutual organization, but is forced by the threat of potential entry to behave competitively. Such behavior in this setting would lead to zero profits or, equivalently, to the bank paying out to depositors everything it receives on the assets it holds. Suppose that such a bank proposes to pay (x_1, x_2) per unit deposited, with x_t being the per unit payment to time t withdrawals, and suppose that the fraction α_t of total deposits D is withdrawn at time t. Then the condition that the bank pay out all earnings is easily seen to be

(6) $$x_2 = R_2(R_1 - \alpha_1x_1)/\alpha_2.$$

One way for such a bank to attract deposits is to provide depositors with a high return on early withdrawals. The highest such return consistent with type 2 depositors not wishing to withdraw is[4]

(7) $$x_1 = \delta_2x_2.$$

When augmented by a suspension rule that no more than α_1x_1D will be paid out at time 1, this kind of banking policy, with depositors choosing how much to deposit, produces the outcome $\tilde{c}$.

This can be seen as follows. With (x_1, x_2) given by the solution to (6) and (7), depositing y in such a bank leads to $(c_1^1, c_2^2) = [\delta_2R_1R_2y/(\alpha_2 + \alpha_1\delta_2R_2)](1, 1/\delta_2)$, a pair that satisfies equation (2) and $c_1^1 = \delta_2c_2^2$. (See Figure 3.) It follows that any pair (c_1^1, c_2^2) on the line connecting that pair and the pair (R_1y, R_1R_2y) can be achieved by dividing the endowment y between autarkic investment and such deposits. Since $\tilde{c}$ is on this line and is, by construction, the preferred pair, the endowment will be split so that $\tilde{c}$ is achieved. Finally, the suspension policy assures that no one has an incentive to misrepresent her or his type no matter what others are expected to do.

More generally, the outcome $\tilde{c}$ can be achieved by individuals splitting their endowment among different banks—banks which propose payment streams that satisfy (6), but which differ according to whether they have relatively high time 1 or time 2 payments per unit. Besides more closely resembling actual banking arrangements, such arrangements can achieve allocations that are optimal even if people at $t = 0$ are allowed to differ. In particular, people could have different endowments and different preferences in the form of different g functions. Different people would then be

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[3]For further discussion of this point, see Andrew Postlewaite and Xavier Vives' 1987 paper.

[4]As is standard, I assume that people truthfully reveal their type if they are indifferent between doing so and not doing so.

holding different portfolios, different amounts of the different kinds of deposits and of autarkic investment.

I conclude this description of the version of the model without aggregate risk by pointing out the sense in which isolation at $t=1$ is necessary for the existence of intermediation in this model. Without isolation at $t=1$, there would in general be a credit market at $t=1$ for one-period loans to be repaid at $t=2$. Following Charles Jacklin (1987), I can show that such a credit market is inconsistent with people voluntarily choosing to deposit at $t=0$, not misrepresenting their type at $t=1$, and with payments per unit of deposits (x_1, x_2) that satisfy (6) and $x_1 > R_1$ (illiquidity).

Note that (6) and $x_1 > R_1$ imply that $x_2 < R_1R_2$ and, therefore, $x_2/x_1 < R_2$, a marginal gross return on deposits between $t=1$ and $t=2$ that is less than R_2. To display the inconsistency, I denote by r the gross return in the loan market at $t=1$ and consider two exhaustive possibilities for r. First, suppose $r > x_2/x_1$. Then any type 2 depositor would attempt to withdraw at $t=1$ and lend at r, thus implying misrepresentation. Next, suppose $r \leq x_2/x_1$. Then no one would choose deposits at $t=0$. By choosing autarkic investment, people assure themselves $c_2^2 = R_1R_2y$. If they turn out to be type 1, then at $t=1$ they borrow at r, pledging their real investment as collateral. Per unit placed in autarkic investment, they can borrow $R_1R_2/r \geq R_1R_2/(x_2/x_1) > x_1$, the last inequality following from $x_2 < R_1R_2$. Thus, they do better with autarkic investment no matter what type they turn out to be.

This shows that access to a credit market at $t=1$ is inconsistent with deposits that provide liquidity. Isolation at $t=1$ is needed to rule out such a credit market.

□ *With Aggregate Risk*

Although the version of the model without aggregate risk explains illiquid intermediary portfolios, the Diamond and Dybvig suspension arrangement works so well there that no difficulties accompany the illiquidity. In particular, suspensions never occur—or certainly never in a way that troubles anyone. Thus, we must conclude that either that version of the model cannot account for the observed difficulties accompanying illiquidity or the suspension arrangement was not thought of. Since the latter seems counterfactual, other variants of the model might better account for the difficulties that accompany illiquidity. The one I consider here, which was also considered by Diamond and Dybvig, is a version in which the fraction of people who will turn out to be type h, α_h, is itself random, so that, in the aggregate, risk exists.

Following Diamond and Dybvig, I will first describe an allocation that gives an upper bound on time 0 expected utility, the expected value of $U(c)$. This upper bound is fully analogous to $\tilde{c}$ above in that it is found by maximizing the expected value of $U(c)$ given by Assumption 4, subject only to Assumptions 1–3 and 6. Then I present the argument that this upper bound cannot be achieved given isolation and, hence, sequential service at $t=1$. An argument of this sort was presented by Diamond and Dybvig and used by them to conclude that intermediation subject to sequential service could not achieve the upper bound.

Diamond and Dybvig, however, went on to describe a policy, which they labeled *deposit insurance*, that could attain the upper bound. Since I insist that any arrangement must be consistent with all the assumptions, I conclude that Diamond and Dybvig's policy is not feasible. I then show that for some economies satisfying all the assumptions, it is desirable to have payments during period 1 depend on the random order in which people contact the machine. Versions of this dependence can be interpreted as nontrivial bank suspensions in which people who show up early get more than those who show up late. Such suspensions are nontrivial in that those who show up late end up worse off than those who show up early.

The upper bound I begin with permits period 1 consumption of each person to depend on the aggregate fractions of types (α_1^k, α_2^k), which I denote by α^k. (In doing this, I am for the moment ignoring Assumption 5 and the even more important Assumption 7, the isolation assumption.) The upper bound is the solution to the following problem. Choose $C_1(\alpha^k)$, $C_2(\alpha^k)$, and $c(\alpha^k)$ for $k = 1, 2, \ldots, K$, where $c(\alpha^k)$ is the 4-tuple $(c_1^1(\alpha^k), c_1^2(\alpha^k), c_1^2(\alpha^k), c_2^2(\alpha^k))$, to maximize

$$(8) \qquad E(U(c)) \equiv \textstyle\sum_k p_k \left[\sum_h \alpha_h^k u^h(c_1^h(\alpha^k), c_2^h(\alpha^k))\right]$$

subject to, for $k = 1, 2, \ldots, K$,

$$(9) \qquad C_2(\alpha^k) \leq R_2[NR_1y - C_1(\alpha^k)]$$

$$(10) \qquad C_1(\alpha^k) = \alpha_1^k N c_1^1(\alpha^k) + \alpha_2^k N c_1^2(\alpha^k)$$

$$(11) \qquad C_2(\alpha^k) = \alpha_1^k N c_2^1(\alpha^k) + \alpha_2^k N c_2^2(\alpha^k)$$

where E denotes expectation and (α^k) denotes dependence of the variable on the outcome for (α_1, α_2).

Although this problem looks complicated, it is as simple as the upper bound problem considered in the version of the model without aggregate risk. Note that (9) is the same as (1) except for the dependence on α^k. Also note that the variables $C_1(\alpha^k)$, $C_2(\alpha^k)$, and $c(\alpha^k)$ for a particular k appear in only one term of the sum in (8) and appear in only the kth equation of each of (9), (10), and (11). Therefore, the maximization can be accomplished separately for each value of k. Moreover, each of these maximizations is exactly like the one above except that (α_1, α_2) is replaced by the kth value of (α_1, α_2). Thus, if I denote by $\tilde{c}(\alpha^k)$ the kth 4-tuple that solves this problem, Assumption 4 implies that $\tilde{c}_2^1(\alpha^k) = \tilde{c}_1^2(\alpha^k) = 0$ and

(12) $\tilde{c}_2^2(\alpha^k) = R_2[NR_1y - \alpha_1^k\tilde{c}_1^1(\alpha^k)]/\alpha_2^k$

(13) $g'(\tilde{c}_1^1(\alpha^k))/g'(\delta_2\tilde{c}_2^2(\alpha^k)) = \delta_2R_2.$

The pairs $(\tilde{c}_1^1(\alpha^k), \tilde{c}_2^2(\alpha^k))$ for two values of k $(k = 1, 2)$ are displayed in Figure 4. As there depicted, the pair for the smaller value of α_1 has higher values of both c_1^1 and c_2^2, which is a direct consequence of (13). This fact is used below.

I now show that $\tilde{c}(\alpha^k)$ for $k = 1, 2, \ldots, K$ cannot be achieved. That is, given Assumptions 7 and 8, the machine cannot be programmed in a way that permits $\tilde{c}(\alpha^k)$, $k = 1, 2, \ldots, K$, to be achieved. To see this, we need only consider what happens if the first person to contact the machine is a type 1 person. Except in trivial cases, neither this person nor the machine knows α^k. Hence, this person must get a payment that does not depend on α^k. But as noted above, $\tilde{c}(\alpha^k)$ for $k = 1, 2, \ldots, K$ does depend on α^k. Therefore, $\tilde{c}(\alpha^k)$ cannot be achieved.

Now I use this result to show that Diamond and Dybvig's deposit insurance is inconsistent with Assumptions 7 and 8. Although this insurance scheme is quite complicated, for my purpose here I need only note that it achieves $\tilde{c}(\alpha^k), k = 1, 2, \ldots, K$. Since I just established that no arrangement consistent with Assumptions 7 and 8 can achieve $\tilde{c}(\alpha^k)$, I conclude that Diamond and Dybvig's deposit insurance scheme does not satisfy those assumptions.

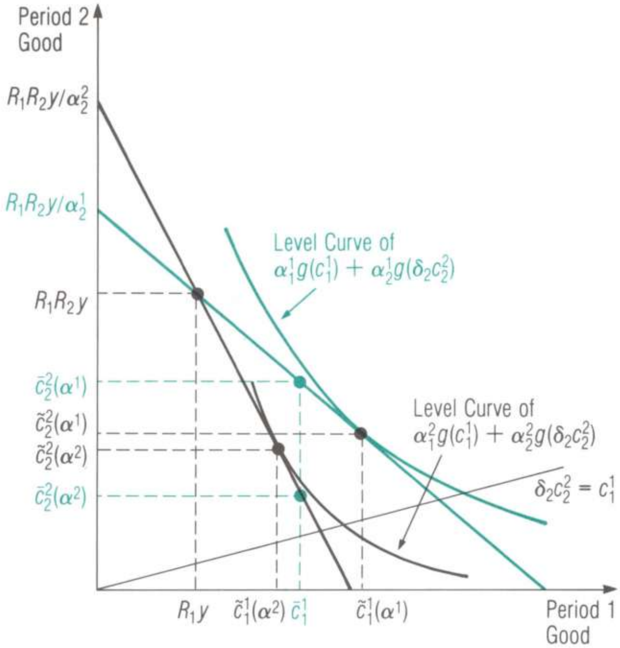
Indeed, as must be the case, the Diamond and Dybvig deposit insurance scheme allows the insuring (and taxing) agency to cumulate all period 1 withdrawal demands and make a payment contingent on the total. Such an arrangement violates isolation at $t = 1$.

Note that this argument does not say that any kind of deposit insurance scheme is infeasible. It only says that the policy that Diamond and Dybvig identify with deposit insurance is infeasible and, therefore, that they have not provided a coherent case for deposit insurance. Other kinds of deposit insurance schemes may be feasible and desirable.

Figure 4

Optimal Consumption
With Aggregate Risk

$\tilde{c}$: Subject Only to Assumptions 1–3 and 6
$\bar{c}$: Subject Also to No Dependence on the Order People Contact the Machine



Having shown that $\tilde{c}(\alpha^k)$ is not achievable, I naturally ask, What is the best achievable arrangement? Unfortunately, I do not have a complete answer. I can, however, show that there are economies in which the most desirable arrangement will have realized period 1 consumption dependent on the order in which type 1 people contact the central location. I can do this by showing that a symmetric arrangement satisfying all the assumptions and for which realized period 1 consumption depends in a simple way on that ordering gives higher expected utility than any feasible symmetric arrangement that does not display any such dependence.

The first step in my argument is to note that if period 1 consumption does not depend on ordering, then it is constant. In particular, it cannot depend on the realization of α^k. Therefore, an upper bound on expected utility achievable under schemes without dependence on ordering is given by the solution to maximizing (8) subject to (9)–(11) and the additional constraint $c_1^h(\alpha^k) = c_1^h$, a constant not dependent on k. Denote this allocation $\bar{c}(\alpha^k)$ and note that it satisfies $\bar{c}_1^2 = \bar{c}_2^1(\alpha^k) = 0$ and (9) at equality for each k.[5] Now let $K = 2$ so that the nonzero part of $\bar{c}(\alpha^k)$ is a triplet ($\bar{c}_1^1$, $\bar{c}_2^2(\alpha^1), \bar{c}_2^2(\alpha^2)$). Moreover, let the function g be such that this solution satisfies $\bar{c}_1^1 < \delta_2 \bar{c}_2^2(\alpha^k)$ for $k = 1, 2$. If $g(x) = -x^{-b}$ for $b > 0$, then since the solution to maximizing (8) subject to (9)–(11) approaches $c_1^1 = R_1 y$, $c_2^2 = R_1 R_2 y$ as b approaches 0, for sufficiently small b, $\bar{c}_1^1 < \delta_2 \bar{c}_2^2(\alpha^k)$. [The triplet ($\bar{c}_1^1, \bar{c}_2^2(\alpha^1)$, $\bar{c}_2^2(\alpha^2)$) is depicted in Figure 4.]

Now consider the following arrangement. The entire endowment is pooled and deposited in the machine. For some positive ϵ still to be determined, the payment on a period 1 withdrawal is $(\bar{c}_1^1 + \epsilon)$ until withdrawals total $N\alpha_1^1(\bar{c}_1^1 + \epsilon)$. The payment on subsequent period 1 withdrawals is $(\bar{c}_1^1 - \epsilon)$ until withdrawals total $N[\alpha_1^1(\bar{c}_1^1 + \epsilon) + (\alpha_1^2 - \alpha_1^1)(\bar{c}_1^1 - \epsilon)]$, or $N[\alpha_1^2 \bar{c}_1^1 + \epsilon(2\alpha_1^1 - \alpha_1^2)]$. Then no further withdrawals at $t = 1$ are allowed. (Such period 1 payments are depicted in Figure 5.) Finally, at $t = 2$, all resources are divided on a pro rata basis among those who have not withdrawn at $t = 1$.

Note that in this arrangement, since $\bar{c}_1^1 < \delta_2 \bar{c}_2^2(\alpha^k)$ for $k = 1, 2$ and since payments are totally suspended after withdrawals total $N[\alpha_1^2 \bar{c}_1^1 + \epsilon(2\alpha_1^1 - \alpha_1^2)]$, for sufficiently small ϵ it is easily shown that everyone has an incentive to behave in accord with their true type. This being so, I assume they do and express expected utility as a function of ϵ.

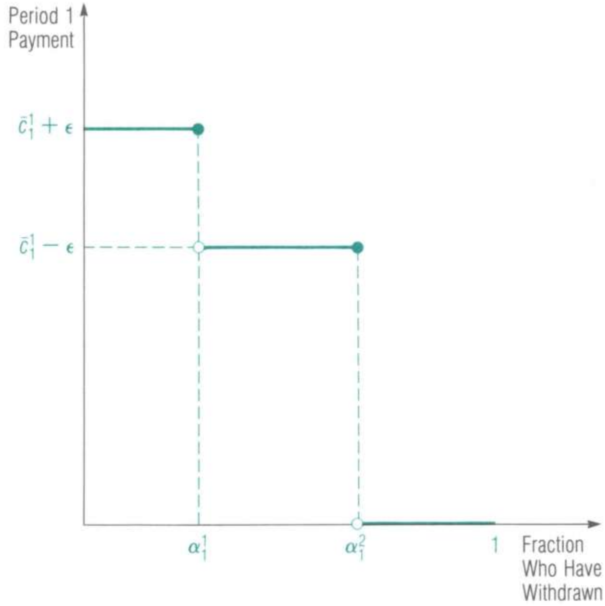
I first express C_1 as a function of α^k and then use (9) at equality and (11) to express $\bar{c}_2^2(\alpha^k)$ as a function of ϵ. By (10), $C_1(\alpha^1)/N = \alpha_1^1(\bar{c}_1^1 + \epsilon)$ and $C_1(\alpha^2)/N = \alpha_1^1(\bar{c}_1^1 + \epsilon) + (\alpha_1^2 - \alpha_1^1)(\bar{c}_1^1 - \epsilon)$. In each case, $\bar{c}_2^2(\alpha^k) = R_2[R_1 y - C_1(\alpha^k)/N]/\alpha_2^k$. Then, from (8), expected utility is

$$(14)\quad G(\epsilon) = p_1[\alpha_1^1 g(\bar{c}_1^1 + \epsilon) + \alpha_2^1 g(\delta_2 \bar{c}_2^2(\alpha^1))] + p_2[\alpha_1^2(\alpha_1^1/\alpha_1^2) g(\bar{c}_1^1 + \epsilon) + \alpha_1^2(1 - \alpha_1^1/\alpha_1^2) g(\bar{c}_1^1 - \epsilon) + \alpha_2^2 g(\delta_2 \bar{c}_2^2(\alpha^2))]$$

where α_1^1/α_1^2 is the probability conditional on $\alpha = \alpha^2$ that a type 1 person contacts the machine early enough to get the return $(\bar{c}_1^1 + \epsilon)$ and $(1 - \alpha_1^1/\alpha_1^2)$ is the probability that the person is too late and gets only $(\bar{c}_1^1 - \epsilon)$.

Figure 5

How the Period 1 Payment Could Depend on When a Person Contacts the Machine



The derivative of G with respect to ϵ evaluated at $\epsilon = 0$ is

$$(15)\quad G'(0) = p_1 \alpha_1^1 H(\alpha^1) + p_2(2\alpha_1^1 - \alpha_1^2) H(\alpha^2)$$

where $H(\alpha^k) \equiv g'(\bar{c}_1^1) - \delta_2 R_2 g'(\delta_2 \bar{c}_2^2(\alpha^k))$. Since $\bar{c}(\alpha^k)$ is the solution to maximizing (8) subject to (9)–(11) and $c_1^1(\alpha^k) = c_1^1$, H satisfies

$$(16)\quad p_1 \alpha_1^1 H(\alpha^1) + p_2 \alpha_1^2 H(\alpha^2) = 0.$$

Substituting from (16) into (15), we get $G'(0) = p_2 2(\alpha_1^1 - \alpha_1^2) H(\alpha^2)$. Since $\alpha_1^1 < \alpha_1^2$, $g'' < 0$, and $\bar{c}(\alpha^k)$

[5] An additional assumption is needed to conclude that $\bar{c}_2^1(\alpha^k) = 0$ for all k. The reasoning used in note 2 can be applied here to establish that $\bar{c}_1^2 = 0$ and that $\bar{c}_2^1(\alpha^k) = 0$ for some k. However, because c_1^1 is not permitted to vary with k, the reasoning cannot be used in the same simple way to establish that $\bar{c}_2^1(\alpha^k) = 0$ for all k. A simple alternative argument is available if we assume that $\delta_1 = 0$. Then an allocation with $c_2^1(\alpha^k) > 0$ for some k can be dominated by a feasible allocation with $c_2^1(\alpha^k) = 0$ and with the released state k, time 2 output used to augment $c_2^2(\alpha^k)$.

satisfies (9) at equality, the definition of $H(\alpha^k)$ implies that $H(\alpha^2) < H(\alpha^1)$. This inequality and (16) imply that $H(\alpha^2) < 0$, which implies that $G'(0) > 0$. This completes the argument because it implies that there are positive ϵ for which the scheme illustrated in Figure 5 gives higher expected utility than the best scheme that does not have any dependence on ordering.

Note that this result does not describe the best symmetric arrangement. That is, even for this simple $K = 2$ case, I have not found an arrangement that maximizes expected utility subject to all the assumptions. However, for some economies I have found an arrangement that satisfies those assumptions and gives higher expected utility than any feasible arrangement that does not make consumption depend on the order people contact the central location at $t = 1$. Thus, I can conclude that for those economies the best arrangement displays some such dependence.

Although this dependence property of an equilibrium has been established only for a very special class of economies, it almost certainly holds quite generally. Arrangements that do not display such dependence necessarily limit randomness to period 2 consumption. In general, higher expected utility should be achievable using arrangements that shift some of the randomness to period 1 consumption even if the shifting is accomplished by introducing a new source of randomness—dependence on ordering—that by itself is utility reducing. Indeed, a plausible conjecture is that aggregate randomness in the desired intertemporal pattern of consumption and some version of the isolation assumption are in general sufficient to imply that equilibrium arrangements involve some dependence of returns on the order people withdraw.

In this connection, note that under an arrangement in which returns are a decreasing function of earlier withdrawals, as in Figure 5, the model's features resemble qualitative features of U.S. banking experience during the 19th century. In particular, during actual suspension episodes, those who withdrew late, after suspension occurred, received a lower return than those who withdrew early; late withdrawers' checks passed at a discount. According to this interpretation, such suspension episodes are the result of high realizations of the fraction who want to consume early; they are not runs in the sense of type 2 people claiming to be type 1 people.

Finally, note that this interpretation of suspension episodes can be adopted without the claim that bankers or depositors had anything like the model's perspective on feasible banking arrangements. Bankers would adopt such payment patterns in order to lessen the impact of aggregate uncertainty on future returns or, as some have said, in order to protect bank assets. People would be willing to obtain deposits with such payment patterns—that is, even knowing that suspensions might occur—because such deposits have a relatively high return in some circumstances. However, without the model's perspective on feasible arrangements, there could easily be dissatisfaction with the system and a search for a better one. After all, some depositors getting lower payments simply because they show up later than some others seems disorderly and to impose on depositors an undesirable degree of uncertainty. Without the perspective offered by this model, it is hardly surprising that people would not consider such uncertainty to be an unavoidable consequence of features of the environment—aggregate uncertainty and the features that make sequential service necessary.

Concluding Remarks

In this paper, I have described a model of banking very like Diamond and Dybvig's. In it I assume an environment that is different from theirs in only one way: I assume that people are isolated at the early withdrawal time in a way that implies Diamond and Dybvig's sequential service constraint. Admittedly, I have been able to obtain only limited results. Isolation turns out to be important in constraining what can be achieved in the version of the model with aggregate risk, the version in which the total number of people who truly need to withdraw early is random. However, for that version, I was able to obtain only a weak general property of the best arrangement in some special cases, namely, that returns on early withdrawals depend on the random order people withdraw. Obviously, when isolation constrains what can be achieved, it does so in a complicated way.

Despite that, I think isolation must be retained in some form because the alternative, that people are together at the early withdrawal time, is inconsistent with illiquid banking arrangements in two senses. First, if people are not isolated, then the arrangements that potentially achieve good outcomes do not resemble banking. In the camping trip economy, for example, a late-night meeting would be held, people would be asked whether they are hungry, and the magnitude of the late-night snack would be based on their responses. Second, if people are not isolated, then they could and, in general, would want to participate in a one-period credit market at the early withdrawal time. As demonstrated above, such a market is inconsistent with voluntary participation in an illiquid banking arrangement.

Inconsistency between banking, on the one hand, and well-functioning markets, on the other, should not be surprising. Almost any story about the role of banking has implicit in it that markets are costly to participate in or are incomplete in some way. What distinguishes the model I have presented here is its explicit description of banking services and of what prevents markets from supplanting those services. That explicit description has allowed me to deduce results rigorously. Besides the result that returns depend on ordering, I have deduced that Diamond and Dybvig's kind of deposit insurance is not feasible and that policies that directly limit the illiquidity of bank portfolios, although feasible, are not desirable.

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