NBER WORKING PAPER SERIES

# BANKING IN GENERAL EQUILIBRIUM

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Working Paper No. 1647

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
June 1985

Prepared for the Conference on New Approaches to Monetary Economics in May 1985, Austin, Texas. The research reported here is part of the NBER's research program in Economic Fluctuations. Any opinions expressed are those of the authors and not those of the National Bureau of Economic Research.

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# Banking in General Equilibrium


ABSTRACT

This paper attempts to provide a step towards understanding the role of financial intermediaries ("banks") in aggregate economic activity. We first develop a model of the intermediary sector which is highly simplified, but rich enough to motivate several special features of banks. Of particular importance in our model is the assumption that banks are more efficient than the public in evaluating and auditing certain information-intensive loan projects. Banks are also assumed to have private information about their investments, which motivates the heavy reliance of banks on debt rather than equity finance and their need for buffer stock capital.

We embed this intermediary sector in a general equilibrium framework, which includes consumers and a non-banking investment sector. Mainly because banks have superior access to some investments, factors affecting the size or efficiency of banking will also have an impact on the aggregate economy. Among the factors affecting intermediation, we show, are the adequacy of bank capital, the riskiness of bank investments, and the costs of bank monitoring. We also show that our model is potentially useful for understanding the macroeconomic effects of phenomena such as financial crises, disintermediation, banking regulation, and certain types of monetary policy.



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## 1. *Introduction*

The Miller–Modigliani theorem asserts that economic decisions do not depend on financial structure in a setting of perfect capital markets. An implication is that the addition of financial intermediaries to this environment has no consequence for real activity. A number of authors (e.g. Bernanke (1983), Blinder and Stiglitz (1983), Boyd and Prescott (1983), Townsend (1983)), recently have questioned the relevance of these propositions. They revive the earlier view of Gurley and Shaw (1956), Patinkin (1961), McKinnon (1973), and others that financial intermediaries provide important real services to the economy, and that the provision of these services has substantive implications for macroeconomic behavior. The basic premise is that, in the absence of intermediary institutions, financial markets are incomplete. This incompleteness arises primarily because of certain informational problems. By specializing in gathering information about loan projects, financial intermediaries help reduce market imperfections and thus facilitate lending and borrowing. Accordingly, changes in the level of financial intermediation due to either monetary policy, legal restrictions, or other factors, may have significant real effects on the economy. Bernanke, for example, argued that the severity of the Great Depression was due in part to the loss of intermediary services suffered when the banking system collapsed in 1930–33.

This paper is an analysis of the role of financial intermediaries in the determination of general equilibrium. (From now on, we refer to financial intermediaries simply as "banks".) Our objective is to provide a step toward understanding the role of banks in aggregate economic activity. We employ a model of the banking sector which is highly simplified but is rich enough to motivate several special features of banks. When embedded in a broader general equilibrium setting, this model implies that banks play an important role in real allocation and are not merely financial veils. Critical to this result is the premise that both banks and depositors have private information about certain aspects of their respective opportunities and needs. With no private information financial intermediation would be irrelevant to economic activity, as in the Miller–Modigliani analysis.

There are three distinguishing characteristics of banks that are particularly important for our purposes. First, banks specialize in the provision of credit for projects which, because of high evaluation and monitoring costs, cannot easily be funded by the issuance of securities on the open market. The "information intensity" of bank investments, in turn, makes it difficult for outsiders to ascertain the value of bank assets at any given moment. Second, banks finance their lending by the issuance of liabilities which are, for the most part, non-contingent claims, and which are typically more liquid than bank assets. Finally, bank capital (although small relative to bank assets) plays a vital role as a "buffer"; i.e., the existence of capital allows banks to meet fixed interest obligations despite variations in deposits or asset returns.[1]

The seminal work of Jensen and Meckling (1976), which first noted the potentially great importance of ownership structure in settings with agency costs, may be used to support the view that these features of banking are interdependent. For example (following a standard J-M argument), the high ratio of debt to equity financing by banks (and the associated high fixed interest obligation) presumably substitutes for direct observability of bank asset values by reducing the latitude of bank managers for shirking or peculation. Similarly, as Cone (1982) has suggested, the very short-term nature of most bank liabilities may provide an additional check on managers, by creating an essentially continuous need for the maintenance of "confidence" in the bank.

Because this paper is about the macroeconomic role of banks rather than the details of banking structure, we do not undertake here a full-blown analysis of agency costs in banking. (Such an exercise would require the modelling of the behavior of at least three groups—bank managers, outside equity holders, and depositors—and would soon become quite complex.) However, by making some strong simplifying assumptions about the privateness of bank portfolios, we are able to derive, in a way that is both internally consistent and in the spirit of Jensen–Meckling, some features of banking relevant to macroeconomic performance. It is our belief that the results we get are at least suggestive of what would be obtained with a richer and more realistic microeconomic model of banking.

We begin our simplified analysis of the banking sector with the assumption that there exists a pool of potential investment projects which are costly both to evaluate and to audit if undertaken. We assume that banks are able to perform two intermediary functions, at a cost: First, they determine which projects in the pool are "viable" and worthy of investment. Second, they monitor the projects in which they invest depositor funds in order to determine

[1] An additional important feature of banks, which we will not however emphasize in this paper, is their role in facilitating transactions. For a model of banking that focuses on their transactions role, see Fischer (1983).

their true ex post returns. We hypothesize that there exists an informational economy of scope in ex ante and ex post project evaluation to motivate why a single institution performs both of these functions. Further, it is assumed that the banks' evaluation and auditing technology requires a fixed setup cost, which discourages individuals from independently evaluating projects.

The information that a bank obtains, about both ex ante project viability and actual ex post project returns, is taken to be the private knowledge of the banker. This assumption is admittedly overstated, but it reflects what many argue is a crucial aspect of banking: the intimacy and privateness of the relationship between banks and their loan customers (especially long-term customers with complex or non-standard credit needs). For example, Diamond (1984) gives an excellent exposition of how banks typically establish a close relationship with loan customers, which is maintained through the application process and through the life of the loan; this extended relationship is necessary to monitor whether loan covenants are being satisfied. As Diamond argues, because information about the current status of outstanding loans is costly to obtain and highly idiosyncratic, it is not easily observed by bank depositors or other outsiders.[2] For our purposes, the assumption that banks' information is private is a convenient way to introduce agency costs in banking in a manner that makes the general equilibrium analysis tractable. One can view our postulated information structure and its implications as a stand-in for a more complex agency model.

Although simple, the above framework allows us to motivate the three features of banking given above. First, the fixed cost of the evaluation and auditing technology explains the need for specialization (by banks) in the provision of credit for certain projects. Second, the premise that the information a bank acquires about its loan projects is not publicly observable rationalizes in a simple way, and in a way consonant with the agency-cost approach, the heavy reliance of banks on debt finance: Since bank creditors cannot directly observe the return on the bank's portfolio, they will not accept claims with returns contingent on this information, because of the potential for dissembling on the bank's part (the moral hazard problem). It follows that equity contracts are inadmissible, and that

[2] Indeed, Peltzman (1970) notes that even professional bank examiners typically focus on the quantity of bank capital relative to the quantities of certain broad categories of loans, since individual bank assets are so difficult to value.

banks must issue debt to finance investment.[3] Finally, the privateness of the bank's portfolio and the associated reliance of the bank on debt finance implies that banks must hold a "buffer stock" of capital, in order to guarantee the returns on their liabilities.[4] Depositors will accept non-contingent claims only from banks which can meet their obligations under all possible outcomes of their respective portfolios.[5] Hence, banks must have net assets in order to self-insure, in the absence of comprehensive federal deposit insurance. It follows, as will be seen, that the degree of financial intermediation by banks depends critically on the availability of capital in the banking sector.[6]

A feature of banking which is not motivated by the assumptions made so far is the heavy issuance of banks of demand debt, rather than fixed-term debt. Our choice here is to avoid the difficult-to-model Cone argument mentioned above. Instead, we will appeal to the liquidity insurance argument provided by Bryant (1980) and.elaborated by Diamond and Dybvig (1983): Suppose that individuals face independent liquidity risks, which are not publicly observable. Because of this unobservability, a simple contingent claims market cannot provide insurance. By offering demand deposit-like contracts, banks can provide liquidity insurance to a large number of depositors.[7] [8]

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[3] Cone makes a more extended argument for private information about bank asset values as a cause for the issuance of deposits by banks. Similarly, Diamond appeals to the "ex post information asymmetry" to explain why banks issue debt contracts. Note that these information problems cannot be simply resolved by third-party auditing: In the first place, the auditor must incur the (possibly high) monitoring costs already borne by the bank. Second, if the auditor's interest diverge from the depositors (e.g., if there are potential side payments), a new layer of agency costs is added.

[4] Throughout this paper, "bank capital" refers to insider capital, not capital raised through a public issue. Our model is not sufficiently rich to accommodate outsider equity, since we make no distinction between bank owners and bank managers. The notion that bank capital (either inside or outside) is used primarily as a buffer, however, does seem to be realistic (Peltzman, p.1).

[5] This assumes that there is no effective sanction against banks who claim "too often" that their investments didn't pay off. See the discussion in Section 2.

[6] When government deposit insurance does exist, it is usually accompanied by regulations which establish minimum capital requirements for a given amount of intermediation. We expect to address the effects of deposit insurance more directly in later research.

[7] The ability to provide liquidity insurance is not restricted to banks, however. In the analysis of Section 4 below, we will allow consumers to choose between bank-provided insurance and liquidity insurance provided by a non-bank equity sector.

[8] It should also be emphasized that the liquidity insurance argument alone does not explain why the returns on a bank's liabilities are not contingent on the earnings of its assets. In the Diamond-Dybvig model, for example, there is nothing to prevent banks from offering equity contracts which perform the insurance function (Jacklin (1985)). In

Once we have developed the model of banking described above, we will embed it in a stylized general equilibrium framework. Using this framework, we will argue that banks matter to real activity mainly because they provide the only available conduit between savers and projects which require intensive evaluation and auditing.[9] Factors which affect the ability of the banking system to provide intermediation, or which affect the cost of intermediation, will therefore have an impact on the real allocation. Among the factors affecting intermediation, we will show, are the adequacy of bank capital, the riskiness of bank investments, and the costs of bank monitoring. We will show also that our model is potentially useful for understanding the macroeconomic effects of phenomena such as financial crises, disintermediation, banking regulation, and certain types of monetary policy.

The paper is organized as follows. In Section 2, we describe a general equilibrium model with consumers and banks. Section 3 characterizes the dynamic and steady state equilibria of this model. In Section 4, we analyze how the equilibrium is affected by the addition of a non-banking investment sector (in which there are none of the information problems that exist in the banking sector). Section 5 discusses some applications and Section 6 concludes.

## 2. *Setup of the Basic Model with Consumers and Banks*

We consider an economy with the following production possibilities. There is one type of output, a consumption good. The consumption good is perishable and must be consumed in the same period that it is produced. The only input is an endowment good, which cannot be consumed immediately. It may either be stored for one period and then consumed (one unit of endowment yielding one unit of consumption), or invested in a project which yields a random amount of output in two periods. We refer to these two methods of converting the endowment good to the consumption good as the liquid and illiquid investments respectively. An important additional feature of the latter is that, in the absence of costly monitoring, it is not possible to evaluate the quality of a project ex ante nor to observe its returns ex post. This characteristic motivates the need for institutions, such as banks, which specialize in gathering information about investment projects.

our framework, however, depositors other than insiders will not accept equity contracts because the performance of the bank's assets is private information.

[9] This follows from the assumption of extreme non-substitutability between bank and non-bank assets. Some comments on the realism of this assumption for the contemporary economy are given in the Conclusion.

The consumer sector consists of overlapping generations of identical agents, each of whom lives three periods. The population of consumers is represented as a continuum of constant length. Each newly born agent receives $W$ units of the endowment good, but does not consume until either the second or third period of life. Individuals face idiosyncratic liquidity risks, as in Diamond and Dybvig. A fraction $\alpha$ of the population born at time $t$ are type I's who receive utility from consumption only in $t+1$, and, conversely, $(1-\alpha)$ are type II's who receive utility only in $t+2$. An individual agent's type is private information. However, agents must decide how to allocate their endowment before they learn their respective types. The options are storage and lending to the banking system. Individuals can store endowment if they wish, but they cannot directly invest in illiquid projects because evaluation and auditing of the projects are prohibitively costly. In Section 4 below we will introduce an alternative two-period technology (an equity sector), in which opportunities and returns are costlessly observable.

The banking sector has the following properties. There exist a fixed number of agents distinct from consumers, termed bankers, who are infinitely-lived and risk neutral.[10] Bankers intermediate resources between consumers and investment projects. They sell their liabilities to consumers in exchange for endowment. Further, each banker owns a physical asset, referred to as bank capital, which yields an additional $W_b$ units of the endowment good each period. (Bank capital is postulated in order to provide a source of insider equity, which is necessary to overcome the agency problems in this model.) After receiving consumers' deposits and the proceeds of their own capital good, bankers must decide how to allocate the endowment received from these various sources between the liquid and illiquid investment projects.

Each banker owns and operates a technology for evaluating and auditing illiquid investment projects; we assume that, without this technology, it is impossible to locate and invest in "viable" projects (i.e., projects that pay positive returns). The returns to viable projects are random: We assume that all viable projects have the same ex ante return distribution,

[10] The risk-neutrality assumption plays no critical role but is adopted for convenience. It is also possible to conduct the analysis with finite-lived bankers; however, in this case certain inefficiences arise in equilibrium which we do not consider to be fundamentally interesting. The exogenous division of the population into bankers and non-bankers is a weakness of our model; see Boyd and Prescott for a model in which this division is endogenous.

but that the ex post realizations of individual project returns may differ. The degree of correlation between the realizations of the investment projects of a given bank or across banks does not matter much for our story; for concreteness, we will assume that realized returns are independent. The bank's technology also allows it (privately) to observe the true realization of its investment project's return.[11] As we have mentioned, the assumption that the true return from its investments is seen only by the bank is an important one; its purpose here is to provide a simple agency cost motivation for debt finance by banks.

Note that we are proceeding as if banks invest in projects directly, rather than indirectly through the provision of credit to entrepreneurs. Thus this paper differs from much earlier work on banking which has focussed on optimal bank lending arrangements. We employ the simpler characterization of the bank investment process since it seems to capture the features that are most important for our analysis—principally, that the returns to bank investment are random and that these returns are not perfectly observable by the public.

We also assume that there is associated with an individual bank's evaluation and auditing technology a large fixed cost. This fixed cost prevents the direct evaluation of projects by individual consumers.[12] This fixed cost is assumed to be paid once, at the beginning of time (and before the span of time analyzed by the model), rather than each period; having the fixed cost being incurred each period would have no important effect on the results.

For simplicity, we take the marginal evaluation and auditing cost to be constant and equal to $\delta$ over the relevant range; thus, the variable cost function is equal to $\delta I$, where cost is measured in units of endowment and $I$ is the number of viable (illiquid) investment projects undertaken.[13] It is important to our story that no single bank make all the

[11] As noted earlier, the assumption that the same technology is used for evaluation and for auditing is rationalized by the existence of informational economies of scope between these two functions. We believe that these economies are practically of great importance; without them we would probably observe considerably more decoupling of these two functions than in fact we do.

[12] This assumption is unnecessarily strong. What is essential is that bank credit and other sorts of credit not be perfect substitutes. There is evidence that the imperfect substitutability assumption is realistic; see, e.g., Fama (1985).

[13] We take the evaluation cost function to be deterministic, also for simplicity. In an environment where the bank is sampling potential investments in search of viable candidates, it is more natural to think of these costs as random. The extension to a random cost function, given the risk-neutrality of banks, is not difficult. In particular, note that if

investments in the economy (since if a bank can achieve perfect diversification the agency problem disappears). We must therefore assume that the marginal evaluation and auditing cost begins to grow quickly beyond some point (e.g., when $I$ exceeds the maximum number of investments in the economy divided by the number of banks). Alternatively, we might assume that the fixed cost incurred by the bank gives it access only to a limited pool of projects.

Let $L_t$ (for liabilities) be the flow of new endowment the bank borrows from others at time $t$ (below we will allow for the possibility that the bank sells liabilities to other banks as well as to consumers), $S_t$ the amount of endowment the bank invests in the liquid asset (storage), and $h(I_t)$ the *total* cost in endowment of investing in $I$ illiquid assets. The bank's resource constraint at each moment is given by

$$L_t + W_b = h(I_t) + S_t \tag{2.1}$$

where

$$\begin{aligned} h(I_t) &= I_t + \delta I_t \\ h'(\cdot) &= 1 + \delta \end{aligned} \tag{2.2}$$

Equation (2.1) states that the amount of endowment the bank receives from selling deposits and from earnings on bank capital constrains the total level it can invest in the illiquid and liquid projects. According to (2.2), the cost of investing in the illiquid project is the sum of the direct input (assumed to be one unit of endowment per project) and the evaluation and auditing cost.

Banks acquire deposits during each time interval from newly born agents who, as described earlier, expect to receive utility from consumption in either the subsequent period or the one after. Since depositors cannot observe the returns to the banks' illiquid investments, equity contracts are inadmissable. However, at least three basic types of debt–type deposit contracts are possible (plus linear combinations): These are (i) "storage contracts",

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banks are sampling from a large population of i.i.d. potential investments, then the number of draws required to obtain $I$ viable projects obeys a negative binomial distribution. In this case, if each draw incurs a constant cost, the expected cost of finding $I$ viable projects is proportional to $I$, analogous to the above.

that pay the depositor a fixed sum in the second period of life, one period after the initial deposit; (ii) "time deposits" $T$ that pay a fixed sum two periods after the deposit, in the depositor's third period of life; and (iii) "demand deposits" $D$ which, as in Diamond and Dybvig, the depositor may redeem (at his volition, but in an amount that depends on when he withdraws) in either the second or third period of life.[14] Since the consumption good is perishable, and since the period in which the depositor will be able to get utility from consumption is uncertain, it is straightforward to show that storage contracts and/or time deposits will be dominated by demand deposit contracts in equilibrium. The proof, e.g. for time deposits, is to note that the bank can offer at effectively the same real cost a time deposit that pays $r$ and a demand deposit that pays a quantity approaching $r/(1-\alpha)$ (which is greater than $r$) in the second period and an infinitesimal positive quantity in the first period.[15] This demand deposit will always be strictly preferred by the consumer to the time deposit.[16]

Based on these considerations, we therefore take all deposits made by consumers in banks to be representable as demand deposits. In addition, it will be convenient for exposition to allow banks to buy and sell time deposits among themselves.[17] Accordingly, we

[14] The returns to a demand deposit can be written as $(r^1, r^2)$, where $r^1$ is the gross real return to the depositor if he withdraws after one period, and $r^2$ is the return if the withdrawal is made after two periods.

[15] A quantity infinitesimally below $r/(1-\alpha)$ can be offered in the second period since only a fraction $1-\alpha$ of consumers will actually withdraw in the second period. The rest of the consumers, the Type I's, get utility only from first-period consumption and thus will prefer the infinitesimal return available in the first period. Note that in equilibrium the bank will always face a finite rate of transformation between payouts in adjacent periods.

[16] Demand deposits will possibly fail to dominate only when there exist markets in which consumers in the second period of life can trade current consumption and claims on next-period consumption; in this case it is not necessarily possible to rule out time or storage deposits. However, the addition of these markets does not make possible any allocations which are superior to those achievable by the use of pure demand deposits, and may lead to an inferior allocation. In particular, if demand deposits also exist, the existence of such markets introduces the possibility of Diamond-Dybvig-like bank runs. This can occur because these markets provide a means by which Type II consumers may withdraw early (i.e., run on the bank) and still have positive consumption in the third period of life; with perishable consumption, which we have assumed, it could never otherwise pay Type II consumers to run. (See Jacklin for a discussion of a related issue.) It is also not obvious what prices would obtain in these markets, since under our assumptions participants would always have zero marginal utility from the goods or claims that they are selling and strictly positive marginal utility from what they are buying. For these reasons, we rule out these markets, at least for the present paper.

[17] Since storage can be done at any level at zero cost, it is redundant to allow banks to

can disaggregate the net flow of new deposits, as follows:

$$L_t = D_t + T_t - T_{b,t} \tag{2.3}$$

where, again, $L$ is new bank liabilities; $D$ is new demand deposits from consumers; $T$ is new time deposits issued (to other banks); and, also, $T_{b,t}$ is the bank's new holdings of time deposits (at other banks).

Let $\tilde{R}_t$ be the average gross return on the bank's illiquid investment projects realized in period $t$; note that this return pertains to investments made in $t-2$.[18] The random variable $\tilde{R}_t$ is supported on the closed interval $[R^\ell, R^h]$, with $R^\ell < R^h$. We also assume that the following restrictions on the distribution of $\tilde{R}_t$ always hold:

$$R^\ell < 1,$$
$$\beta\overline{R}/(1+\delta) > 1 \tag{2.4}$$

where $\overline{R}$ is the mean of $\tilde{R}$ and $\beta$ is the bankers' common utility discount factor, discussed further below.

Let $r_t^1$ and $r_t^2$ be the rates of return on demand deposits *acquired* at $t$ and redeemed after one and two periods, respectively. Finally, let $r_t$ be the rate of return on time deposits *acquired* at $t$. The expression for the bank's profit $\tilde{\pi}_t$ each period is

$$\tilde{\pi}_t = \tilde{R}_t I_{t-2} + S_{t-1} - \alpha r_{t-1}^1 D_{t-1} - (1-\alpha) r_{t-2}^2 D_{t-2} - r_{t-2}(T_{t-2} - T_{b,t-2}) \tag{2.5}$$

The first term on the right side reflects gross returns from the bank's illiquid investments, made two periods earlier. The second is the return from storing endowment one

trade storage deposits. We have not carefully examined the implications of allowing banks to offer each other demand deposits; this would appear to raise some difficult issues. On this question we only note two points: First, banks would clearly not issue demand deposits to other banks on the same terms that demand deposits are offered to consumers, since the pattern of withdrawals from bank-owned demand deposits would presumably be different from those owned by consumers. Second, the structure of banks' private information about their own portfolios is such that it seems unlikely that the trading of demand deposits would allow a perfect pooling of bank investment risks; only if this conjecture is false would the addition of interbank demand deposits qualitatively affect the results of this paper.

[18] Since the returns to individual projects are i.i.d., the second but not the first moment of $\tilde{R}_t$ will depend on the number of investments made. Since banks are assumed risk-neutral, nothing will be lost by ignoring this dependence.

period earlier in the liquid investment. The last three terms represent the bank's net obligations at $t$. Depositors will withdraw the fraction $\alpha$ (reflecting the percentage of type I's in the population) of demand deposits made one period earlier, and the fraction $(1-\alpha)$ (reflecting the percentage of type II's) made two periods ago.[19] Also, all time deposits either issued or acquired by the bank two periods earlier come due.

Note that the bank's profits come in the form of the perishable consumption good, and therefore must be consumed immediately by the banker. Setting up the model this way rules out the reinvestment of bank profits and makes the bank's optimal control problem essentially deterministic, despite the randomness of returns to the illiquid investment. In particular, the bank's sequential decisions will not depend on the realizations of returns to earlier investments.[20] This substantially simplifies the analysis of the model.

As has been noted, the fact that the returns to bank projects are private information rules out the issuance of contingent liabilities by the bank; we have therefore assumed that the bank issues non–contingent liabilities, i.e., debt. We have also assumed that the number of projects that will be undertaken each period by the bank is "too small" to achieve perfect diversification. This suggests an important question: By what means can the bank guarantee depositors that its obligations will be met?

A potentially interesting set of contracts involves the use of bank capital, or of some other asset of the banker, as a bonding device. (This is the approach used in a similar setting by Diamond (1984).) Under a contract of this form, banks would make a binding promise to forfeit or destroy their capital if they failed to meet their deposit obligations.[21] Contracts with bonding actually re-introduce a degree of contingency into the deposit

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[19] So that we can neglect any uncertainty that banks might have about the proportion of their demand deposits which are withdrawn each period, we will assume that the number of customers at each bank can be represented as a continuum of positive length. (Thus, there are a finite number of banks, which we will nevertheless assume behave competitively.) Alternatively, given that withdrawals are observable, there would be no barrier to banks insuring each other against idiosyncratic withdrawal risk. See Diamond and Dybvig for a discussion of the issues that arise when $\alpha$ is uncertain.

[20] However, as will be discussed, the bank's decisions will depend on the distribution of the returns to the illiquid investments.

[21] In our model, bank capital is not directly consumable, so it could not be used to pay off depositors. Thus both depositors and the bank would be hurt if the bank failed. In practice, the bond posted by bank managers and owners takes the form of a legal commitment to incur the costs of bankruptcy and reorganization, should creditor obligations not be met.

arrangement; such contracts might be desirable ex ante in some cases, even though they allow the possibility of bank failure.

We hope to consider bonding contracts in future research. For the present paper, however, we rule out bonding. Instead, we simply require that the bank plan its investment and storage so as to be able to meet deposit obligations in each period, even under the worst possible set of outcomes on its illiquid investment projects. If the quantities of bank deposits, investment, and storage are observable, this is obviously incentive-compatible. We also conjecture that the behavior of the model will be similar under this regime to what it would be with bonding contracts, with the exception that under the present rule there can be no bank failures.[22] (There can, however, be sharp contractions of the banking system in our model, which for purposes of macroeconomic analysis are essentially equivalent to a wave of bank failures. See Section 5.) Formally, therefore, we require the following condition to hold for all $t > 0$:

$$R^{\ell} I_{t-1} + S_t \geq \alpha r_t^1 D_t + (1-\alpha) r_{t-1}^2 D_{t-1} + r_{t-1}(T_{t-1} - T_{b,t-1}) \tag{2.6}$$

The left side of the inequality is the sum the bank will be able to pay at $t+1$ in the event that all its illiquid investments yield the minimum possible gross return $R^{\ell}$. The right side is the bank's net obligation at $t+1$. In the initial period zero, when the bank has neither investments nor deposits from the past, the relevant constraint is

$$S_0 \geq \alpha r_0^1 D_0 \tag{2.7}$$

Each banker's objective is to choose the sequence $\{I_t, S_t, D_t, T_t, T_{b,t}\}_{t=0}^{\infty}$ to maximize expected discounted profits, i.e.

$$E_0 \left\{ \sum_{t=1}^{\infty} \beta^t \tilde{\pi}_t \right\}, \tag{2.8}$$

subject to constraints (2.1), (2.3), and (2.5)—(2.7), and where $E_0$ is the mathematical expectation operator conditioned on information at time zero and $\beta$ is a subjective discount factor, with $0 < \beta < 1$.

[22] With bonding, it is possible to induce truthful revelation by the bank of its returns over a subset of the outcome space. Normally, however, it will not be possible or desirable (given the costs of bonding) to induce revelation over the entire range of returns. Incentive compatibility will therefore impose a condition of the form of (2.6) below.

To solve the bank's optimal control problem, we may use the resource constraint (2.1) and the deposit relation (2.3) to solve out for total deposits $L_t$ and demand deposits $D_t$; in particular, we are able to remove $D_t$ from both the equation for profits (2.5) and the liquidity constraint (2.6). Hence, $L_t$ and $D_t$ no longer appear directly in the problem. At each time $t$, accordingly, the bank chooses the levels of the illiquid investment $I_t$, of storage $S_t$, and of time deposits issued $T_t$ and acquired $T_{b,t}$. Let $\beta^{t+1}\lambda_t$ be the multiplier associated with the constraint (2.6). Then the first order necessary conditions for $I_t, S_t, T_t$, and $T_{b,t}$ are respectively:

$$\beta[\overline{R} + \lambda_{t+1}R^{\ell}]/(1+\delta) \geq [(1+\lambda_t)\alpha r_t^1] + \beta[(1+\lambda_{t+1})(1-\alpha)r_t^2] \tag{2.9}$$

$$(1+\lambda_t) \geq [(1+\lambda_t)\alpha r_t^1] + \beta[(1+\lambda_{t+1})(1-\alpha)r_t^2] \tag{2.10}$$

$$\beta r_t(1+\lambda_{t+1}) \leq [(1+\lambda_t)\alpha r_t^1] + \beta[(1+\lambda_{t+1})(1-\alpha)r_t^2] \tag{2.11}$$

$$\beta r_t(1+\lambda_{t+1}) \geq [(1+\lambda_t)\alpha r_t^1] + \beta[(1+\lambda_{t+1})(1-\alpha)r_t^2] \tag{2.12}$$

Equation (2.9) states that the expected discounted marginal benefit from investing a unit of endowment in an illiquid project (the left side) must be greater than or equal to the marginal cost (the right side). In addition to providing an expected gross return of $\overline{R}$, having another illiquid investment increases the minimum amount which the bank can guarantee to depositors two periods hence; it therefore may reduce the level of endowment the bank must allocate to liquid projects in the subsequent period in order to satisfy the incentive compatibility constraint (2.6) (updated to apply at $t+1$). The undiscounted value of this marginal benefit is $\lambda_{t+1}R^{\ell}$, where $\lambda_{t+1}$ is the value at $t+1$ of a relaxation of the constraint that requires the guaranteeing of the bank's obligations to depositors at $t+2$. The sum $[\overline{R} + \lambda_{t+1}R^{\ell}]$ is deflated by the marginal cost of investment $1+\delta$, so that the expected marginal benefit is in units of endowment. It also is premultiplied by the discount factor $\beta$, which appears in this expression and elsewhere due to difference in the timing of various benefits and costs.

The marginal cost of investing is the obligation implied by the demand deposit the bank issues in exchange for a unit of endowment. This liability includes both the implied direct payments to depositors and the cost of having to insure these deposits by investing in liquid projects. The latter cost is reflected by the presence of $\lambda_t$ and $\lambda_{t+1}$ in the right side of (2.9).

According to equation (2.10), the marginal benefit from investing in the liquid asset (the left side) cannot be less than the marginal cost (the right side). The former includes both the direct gross return from storage (equal to unity) and the value of having additional liquidity (equal to $\lambda_t$). The marginal cost is the obligation implied by the additional demand deposit liability as before.

Equation (2.11) pertains to how the bank determines its liability structure. It states that the net discounted obligation implied by a time deposit at the margin (the left side), cannot exceed that of an additional demand deposit; otherwise banks would never issue the former type of liability. Conversely, according to (2.12), the value to the bank of an obligation on a demand deposit (the right side) must be less than or equal to the value of the return on time deposits: otherwise banks would never sell the former in order to obtain the latter. Combining (2.11) and (2.12) yields:

$$\beta r_t(1+\lambda_{t+1}) = [(1+\lambda_t)\alpha r_t^1] + \beta[(1+\lambda_{t+1})(1-\alpha)r_t^2] \tag{2.13}$$

How the bank values the respective returns on time and demand deposits must be equal. This condition eliminates the bank's incentive to take an infinitely long or short position in either of the assets.

There are two special cases of equation (2.13) which are of interest. First, assume that the bank is liquidity–constrained ($\lambda_t > 0$, $\lambda_{t+1} > 0$) so that storage is positive. Assume also that storage is finite, so that (2.10) holds with equality. Then combining equation (2.13) with equation (2.10) it can be shown that

$$r_t = \frac{(1-\alpha)r_t^2}{(1-\alpha r_t^1)} \tag{2.14}$$

The relationship between time and demand deposit rates given in the above equation can also be obtained by a simple arbitrage argument. Suppose that the storage constraint is binding in period $t$. On the margin, the bank can always accept an additional demand deposit, store the quantity $\alpha r_t^1$ to provide for withdrawals in $t+1$, and then invest the remainder of the deposit $(1-\alpha r_t^1)$ at the time deposit rate $r_t$. In period $t+2$ the returns from the time deposit must be used to pay off second–period withdrawals in the amount $(1-\alpha)r_t^2$. The returns to this arbitrage activity are thus $r_t(1-\alpha r_t^1)-(1-\alpha)r_t^2$. If this quantity is positive, banks will try to drive their holdings of demand deposits, storage, and of time deposits at other banks to infinity. If this quantity is negative, banks will try to go infinitely short in these assets. This quantity must therefore be zero if storage is positive and finite, which yields (2.14).

The second interesting case, which is the complement of the first, arises when the bank is not liquidity constrained. In this case (2.6) does not hold with equality, so that $\lambda_t$ and $\lambda_{t+1}$ equal zero. Now the bank has no incentive to invest in the liquid asset, since the discounted expected gross return on the illiquid asset $\beta\overline{R}$ exceeds unity, the gross return on storage. Therefore the relevant first order conditions for this case are

$$\beta\overline{R}/(1+\delta) \geq \alpha r_t^1 + \beta(1-\alpha)r_t^2 \tag{2.15}$$

$$\beta r_t = \alpha r_t^1 + \beta(1-\alpha)r_t^2 \tag{2.16}$$

Equation (2.15) is the first order condition for investment in illiquid projects. Equation (2.16) is the arbitrage condition between the bank's valuation of the returns to time and demand deposits; it follows directly from setting $\lambda_t$ and $\lambda_{t+1}$ equal to zero in (2.13). With no storage, the arbitrage condition between deposit rates is simply that the present values of the expected payouts to a time deposit and to a demand deposit must be equal. Comparing (2.16) and (2.14), we note that the relation between time and demand deposit rates changes discontinuously when the banking system moves from a storage equilibrium to one without storage.

### 3. *Equilibrium with Consumers and Banks*

We are now in a position to determine the equilibrium behavior of: (i) bank deposits, and the allocation between demand and time deposits, (ii) investment, and the allocation between illiquid and liquid projects, and (iii) the rates of return on demand and time deposits. A point that we shall want to emphasize is that, because of the existence of private information about bank assets, the equilibrium will be quite sensitive to (1) the availability of bank capital and (2) the minimum possible return to investment in the illiquid project.

So as not to have to keep track of population parameters, we normalize the number of consumers in each generation at unity and also normalize the number of banks at unity. Thus, each period the total endowment received by consumers is $W$ and the yield bankers receive from bank capital is $W_b$.

We recall from an above discussion that we need only consider equilibria in which newly born consumers invest all their endowment in demand deposits. This is because, unlike fixed-term deposits, demand deposits allow these consumers the flexibility to consume in either of the two subsequent periods of life. In equilibrium, therefore, we have

$$D_t = W \tag{3.1}$$

.

3a. *The Behavior of Interest Rates*

At time $t$, the bank offers newly born agents demand deposit contracts which yield $r_t^1$ if withdrawn one period later, and $r_t^2$ if held for two periods. From the discussion at the end of Section 2 it it clear that, on the margin and given $r_t$, the bank is indifferent among combinations of $r_t^1$ and $r_t^2$ which satisfy the arbitrage relation between the returns to time and demand deposits (2.13). Therefore, the pair $(r_t^1, r_t^2)$ which survives in the market place should be the one which maximizes consumers' utility, subject to the relation (2.13).

Assume that $\ln c_{t+1}^I$ and $\rho \ln c_{t+2}^{II}$ are the ex post utility functions for agents born at $t$ who become type I's and type II's, respectively, where $c_j^i$ is consumption by a type $i, i =$ I, II, at time $j$. The representative newly born agent at $t$ then has the following expected utility function:

$$E_t\left\{U\left(c_{t+1}^I, c_{t+2}^{II}\right)\right\} = \alpha \ln c_{t+1}^I + (1-\alpha)\rho \ln c_{t+2}^{II} \tag{3.2}$$

Further since agents allocate all their endowment to demand deposits;

$$c_{t+1}^I = r_t^1 D_t = r_t^1 W \tag{3.3}$$

$$c_{t+2}^{II} = r_t^2 D_t = r_t^2 W \tag{3.4}$$

The equilibrium pair $(r_t^1, r_t^2)$ is the one which maximizes (3.2), subject to (2.13), (3.3), and (3.4). Solving this problem yields

$$r_t^1 = [(1+\lambda_{t+1})/(1+\lambda_t)]\beta r_t/(\alpha + \rho(1-\alpha)) \tag{3.5}$$

$$r_t^2 = \rho r_t/(\alpha + \rho(1-\alpha)) \tag{3.6}$$

We note once again that, due to our assumption that the consumption good is non-storable, it will never pay a Type II agent in our model to withdraw early; thus we can here ignore the incentive compatibility constraints on the demand deposit contract that play an important role in the earlier work of Diamond and Dybvig, Jacklin, and others.

Simpler expressions for $r_t^1$ are available, which depend on whether the liquidity constraint (2.6) is binding. When the constraint is directly relevant, so that (2.10) holds with equality, the expression for $r_t^1$ reduces to a constant.

$$r_t^1 = 1/(\alpha + \rho(1-\alpha)) \tag{3.7}$$

When the liquidity constraint does not bind, so that $\lambda_t$ and $\lambda_{t+1}$ equal zero, $r_t^1$ becomes proportional to the time deposit rate:

$$r_t^1 = \beta r_t/(\alpha + \rho(1-\alpha)) \tag{3.8}$$

It is easily verified that (3.6) and (3.7) together satisfy condition (2.14), and that (3.6) and (3.8) together satisfy condition (2.16).

Finally, we obtain an expression linking the time deposit rate to both the expected return and minimum possible return on the illiquid investment, by appropriately substituting the arbitrage condition (2.13) into the bank's first order condition for investment (2.9):

$$[R + \lambda_{t+1}R^{\ell}]/[(1+\delta)(1+\lambda_{t+1})] \geq r_t \tag{3.9}$$

Equation (3.9) holds with equality, when the same is true for (2.9). Notice that when the liquidity constraint (2.6) is not binding, the time deposit rate depends only on $\overline{R}$ and not on $R^{\ell}$. When $\lambda_{t+1}$ equals zero (3.9) becomes,

$$\overline{R}/(1+\delta) \geq r_t \tag{3.10}$$

3b. *Interest Rates and Investment in the Steady State*

In this section we derive the steady state time deposit rate and allocation of investment. Once the time deposit rate is known, it is then possible to use (3.5) and (3.6) to calculate the associated demand deposit rates. There are three general types of steady state outcomes in which we are interested: (i) Banks invest only in illiquid projects; (ii) they acquire both illiquid and liquid assets; or (iii) they acquire no illiquid assets, except with their own capital; i.e., they invest no depositor funds in illiquid assets. We refer to this last possibility as a *non-banking equilibrium*, since in this case the special function of banks, the investment of depositor funds in information-intensive projects, does not occur. We shall see that whether or not a banking equilibrium (i.e., (i) or (ii)) exists depends critically on the quantity of the yield from bank capital $W_b$.

Before proceeding, it is useful to establish the following preliminary results:

*Lemma 1*: The time deposit rate cannot remain below $1/\beta$ indefinitely.

PROOF: The proof is by contradiction. Suppose that $r < 1/\beta$ for periods $t$, $t+1$, ... We will show that an intermediary which accepts deposits but only invests in liquid projects (a "storage intermediary") will in this case store an infinite amount and make infinite profits, which is inconsistent with equilibrium.

The first step is to note that, for a storage intermediary, the liquidity constraint (2.6) can be written as

$$S_t \geq \alpha r_t^1 S_t + (1-\alpha) r_{t-1}^2 S_{t-1} \tag{3.11}$$

We wish to substitute for $r_t^1$ and $r_t^2$ in this expression. From (3.7) and (3.8) we note that, under the maintained hypothesis,

$$r_t^1 \leq \frac{1}{(\alpha + \rho(1-\alpha))} \tag{3.12}$$

Using this and (3.6), it is straightforward to show that a sufficient condition for the liquidity constraint to be non-binding is

$$S_t > r_{t-1} S_{t-1} \tag{3.13}$$

This condition is always feasible. Thus we may assume that, for a sufficiently high level of storage, the liquidity constraint (2.6) is not binding for the storage intermediary, i.e., $\lambda_t = 0$. A similar argument for $t+1$ shows that, for sufficiently high $S_{t+1}$, $\lambda_{t+1} = 0$.

If $\lambda_t$ and $\lambda_{t+1}$ equal zero (provisionally), the first order necessary condition for investing in a unit of storage at the margin can be written as:

$$1 \geq \alpha r_t^1 + \beta(1-\alpha) r_t^2 \tag{3.14}$$

where the left side is the marginal benefit from storage and the right side is the marginal cost (i.e. the value of the obligation implied by an additional unit of demand deposits). If (3.12) and (3.6) are used to substitute for $r_t^1$ and $r_t^2$, it follows directly that, when $r_t < 1/\beta$, the right side of (3.14) is strictly less than one. Thus the marginal cost of storage will be less than the marginal benefit. This implies an infinite demand for the liquid asset. Similarly, iteration forward shows that there is unbounded demand for storage in each subsequent period; thus our provisional assumption that the liquidity constraint never binds is admissible. Since infinite storage is impossible in equilibrium, we have reached a contradiction and the lemma is proved. ∎

Intuitively, when $r < 1/\beta$, it is possible for a storage intermediary to play an infinite Ponzi game, in which new deposits are used to pay off old obligations. However, this Ponzi game could not be consistent with equilibrium, since it requires (among other things) that the growth rate of deposits exceed the time deposit rate indefinitely. Thus $r$ must not be less that $1/\beta$.

*Lemma 2*: In the steady state with investment only in the illiquid project, the time deposit rate is in the closed interval $[1/\beta, \overline{R}/(1+\delta)]$. When there is storage in the steady state, the time deposit rate equals $1/\beta$.

PROOF: In the steady state where banks invest only in illiquid projects, the expression for the time deposit rate (3.10) becomes $\overline{R}/(1+\delta) \geq r_t$. Thus $\overline{R}/(1+\delta)$ is an upper bound for $r_t$ in this situation. It follows from Lemma 1 that $1/\beta$ is a lower bound.

In the steady state with storage, the bank's first order condition for investment in the liquid asset (2.10) and the arbitrage condition between the time and demand deposit returns (2.13) yield

$$(1+\overline{\lambda}) = \beta r_t (1+\overline{\lambda}) \tag{3.15}$$

where $\overline{\lambda}$ is the steady state value of $\lambda_t$. From (3.15) we obtain $r_t = 1/\beta$. The intuition is that the time deposit rate adjusts to equate the marginal benefit from storage $(1+\overline{\lambda})$ with the marginal cost $\beta r_t(1+\overline{\lambda})$. ∎

We can now characterize the conditions under which various steady state behaviors of investment and the time deposit rate will occur. The value of the dividend from bank capital $W_b$ relative to the consumers' endowment $W$, the minimum return on illiquid investments $R^\ell$, and the liquidity constraint (2.6), it turns out, play critical roles.

*Proposition 1*: Let $x = [\alpha + \rho(1-\alpha)]/[(\beta\alpha + \rho(1-\alpha))(1+\delta)]$. If $xR^\ell(1 + W_b/W)$ is:

(i) $> \overline{R}/(1+\delta)$, then in the steady state banks invest only in illiquid projects, and the time deposit rate equals $\overline{R}/(1+\delta)$;

(ii) $\leq \overline{R}/(1+\delta)$, but $\geq 1/\beta$, then in the steady state banks invest only in illiquid projects, and the time deposit rate equals $xR^{\ell}(1+W_b/W)$;

(iii) $< 1/\beta$, then banks invest some positive fraction of their assets in the liquid project in the steady state, the amount $S^*$ being determined by the following expression:

$$S^* = [((\beta x)^{-1} - R^{\ell})W - R^{\ell}W_b]/[1+\delta - R^{\ell}] \tag{3.16}$$

PROOF: In the steady state without storage the level of investment equals $(1+\delta)^{-1}(W+W_b)$. It follows from the liquidity constraint (2.6) that the following must be true:

$$R^{\ell}(1+\delta)^{-1}(W+W_b) \geq [\alpha r^1 + (1-\alpha)r^2]W \tag{3.17}$$

Substitute (3.6) and (3.8) into (3.17) to obtain

$$R^{\ell}(W+W_b) \geq x^{-1}rW \tag{3.18}$$

where $1/\beta \leq r \leq \overline{R}/(1+\delta)$ according to Lemma 2. Rearranging (3.18) implies

$$xR^{\ell}(1+W_b/W) \geq r \tag{3.19}$$

When the left side of (3.19) strictly exceeds $\overline{R}/(1+\delta)$, the maximum value of $r$, it follows that the liquidity constraint (3.17) holds with strict inequality in the steady state. Thus, the time deposit rate adjusts to equate the expected marginal benefits and costs from investing in the illiquid project (i.e. (2.15) holds with equality):

$$\overline{R}/(1+\delta) = r \tag{3.20}$$

If, however, the left side of (3.19) is less than $R/(1+\delta)$, the liquidity constraint will be violated if $r$ is determined by (3.20). In this case, the time deposit rate must adjust to the maximum value which satisfies (3.19) (so long as this value is greater than or equal to $1/\beta$.) Even though $\overline{R}/(1+\delta)$ exceeds $r$, banks cannot invest more in illiquid projects, because they are liquidity constrained.

When $xR^{\ell}(1+W_b/W)$ is less than $1/\beta$, banks must invest in the liquid asset in the steady state, since $r$ may not fall below $1/\beta$, according to Lemma 1. It follows from (2.6), (3.5), and (3.6), that in order for banks to satisfy the liquidity constraint in this case, the following must be true:

$$R^{\ell}(1+\delta)^{-1}(W+W_b-S^*) + S^* \geq [\beta x(1+\delta)]^{-1}W \tag{3.21}$$

The steady state level of storage is the minimum value of $S^*$ which satisfies (3.21). This value is given by equation (3.16). ∎

Figure 1 illustrates the dependence of the steady state time deposit rate on the lower bound of the return to the illiquid investment and the dividend from bank capital, as defined in Proposition 1: It portrays $r$ as a function of $xR^{\ell}(1+W_b/W)$, the critical term in Proposition 1. It is seen that the time deposit rate is a non-decreasing function of $R^{\ell}$ and $W_b$; increases in $R^{\ell}$ or $W_b$ ease the liquidity constraint, reduce the need for storage, and thus allow a higher return to be paid on deposits. Figure 1 also shows that there is a link between the time deposit rate in the steady state and whether there is positive investment in the liquid asset.

It is also possible that a non-banking steady state equilibrium, in which banks invest no depositor funds in the illiquid project, might arise. Whether this case arises depends critically on the level of bank capital. We have:

*Proposition 2:* If (a) $xR^{\ell}(1+W_b/W) < 1/\beta$ and (b) $W_b/W < \frac{(1+\delta-R^{\ell})}{(R^{\ell}-\delta)}\frac{\rho(1-\alpha)(1-\beta)}{\beta(\alpha+\rho(1-\alpha))}$, then in the steady state there will be no investment of depositor funds in the illiquid project.[23]

PROOF: Condition (a) implies that there will be storage in the steady state, by part (iii) of Proposition 1. It further implies that the steady state level of investment in the illiquid project, $I^*$, satisfies the liquidity constraint

$$R^{\ell}I^* + (W + W_b - (1+\delta)I^*) = [x\beta(1+\delta)]^{-1}W \tag{3.22}$$

or, equivalently

$$I^* = (1+\delta-R^{\ell})^{-1}[W_b + (1-(x\beta(1+\delta))^{-1})W] \tag{3.23}$$

If condition (b) holds, $I^*$ is less than $W_b$. In this case, banks would prefer not to accept deposits and would instead invest only their own endowment in the two-period illiquid technology. We see that a minimal level of bank capital is necessary to provide insurance for deposit obligations when the bank invests depositor funds in risky assets. ∎

Figure 2 shows the steady state relationship between investment as a fraction of consumer endowment, $I^*/W$, and the ratio of bank capital to consumer endowment, $W_b/W$, as defined by (3.22). As $W_b/W$ rises above the threshold defined by (b), banking emerges. Steady-state illiquid investment increases as the ratio of bank endowment to consumer

[23] The parameter $x$ is defined in Proposition 1.

endowment increases, until all of the economy's endowment is devoted to the illiquid investment, i.e., $I = (1+\delta)^{-1}(W + W_b)$. In this last situation, banks have sufficient capital to insure against all outcomes on their portfolio without the need to hold liquid assets; therefore, all endowment can be invested in the more productive illiquid asset.

3c. *Dynamics*

In this section we discuss the dynamic behavior of investment in the illiquid asset, of storage, and of the time deposit rate.

When the liquidity constraint (2.6) is not binding, all resources are invested in the illiquid asset. Otherwise, this constraint governs the investment dynamics. (It is automatically binding in period zero, since the bank has no previous investments to provide revenues to meet deposit obligations in the subsequent period.) Accordingly, by substituting the resource constraint (2.1) and the aggregate relation for deposits (3.1) into equation (2.6), one can obtain a relation for investment in the illiquid asset when the liquidity constraint is binding:

$$I_t = \{R^\ell I_{t-1} - [\alpha r_t^1 + (1-\alpha) r_{t-1}^2]W + W + W_b\}(1+\delta)^{-1} \tag{3.24}$$

Further, substituting (3.7) and (3.6) for $r^1$ and $r^2$ respectively yields

$$I_t = \{R^\ell I_{t-1} + W_b - \frac{(1-\alpha)\rho(r_{t-1}-1)}{\alpha + \rho(1-\alpha)} W\}(1+\delta)^{-1} \tag{3.25}$$

For convenience, we rewrite the relation (3.9), which restricts $r_t$, as follows:

$$\frac{\overline{R} - R^\ell}{(1+\delta)(1+\lambda_{t+1})} + \frac{R^\ell}{(1+\delta)} \geq r_t \tag{3.26}$$

Equation (3.26) holds with equality when the liquidity constraint is binding; when the liquidity constraint does not bind, (3.26) may hold with equality or it may not. (Refer to Proposition 1.)

When equation (3.26) holds with equality note that $r_t$, and therefore $I_t$, depends on the shadow price $\lambda_{t+1}$. When the liquidity constraint is not binding, $\lambda_{t+1}$ simply equals zero. When the constraint does bind, a difference equation for $\lambda$ can be obtained from the bank's first order necessary conditions for the illiquid investment and storage ((2.9) and

(2.11) respectively), which hold with equality under these circumstances. This difference equation is:

$$\lambda_{t+1} = [(1+\delta)/\beta R^{\ell}]\lambda_t + [(1+\delta) - \beta\overline{R}]/\beta R^{\ell} \tag{3.27}$$

The coefficient on $\lambda_t$ exceeds unity. However, it follows from Lemma 1 (which states that $r_t$ cannot fall permanently below $1/\beta$) and from (3.26) and (3.27) that $\lambda$ is bounded above.

Also relevant to the behavior of $\lambda$ is a terminal condition, which depends on which type of steady state arises. The shadow price converges to zero if the steady state involves only investment in the illiquid project (so that the liquidity constraint isn't binding). Otherwise, $\lambda$ converges to a positive constant, defined by the steady state of (3.27).

*Proposition 3.* From any initial position, the model with banks and consumers converges over time to a steady state. (The characteristics of the steady state depend on the parameters of the model. See Proposition 1.)

PROOF: See appendix. ∎

Proposition 3 is useful at least in that it validates the use of comparative statics analysis in applications of the model.

## 4. *Equilibrium with an Alternative, Publicly Observable, Technology*

Until this point we have restricted ourselves to the case in which all productive investment is intermediated by banks. This clearly overstates the importance of financial intermediaries in the economy. In this section we consider the implications of introducing into the model an alternative technology for transforming endowment into consumption goods. Like the storage technology but unlike the illiquid investment technology monitored by banks, this alternative technology is assumed to be costless to observe; that is, monitoring to evaluate the viability of this technology or to observe its returns is inessential. As a result, investment in the alternative technology may be financed by directly issuing securities on the open market; bank credit is unnecessary.

In the general equilibrium with both bank investment and the alternative investment, it turns out that, once again, bank capital and the support of the return distribution for bank illiquid projects play critical roles. In the case discussed in the previous section, these variables were important in determining how the bank allocated its portfolio between liquid and illiquid projects. In the present setting, in which the alternative sector competes with banks for funds, these variables will also help determine the size of the banking sector itself.

4a. *Investment in the Alternative Technology*

We assume that the alternative technology has the following characteristics: An input at time $t$ of $\hat{I}_t$ units of endowment yields $f(\hat{I}_t)$ certain units of consumption two periods later. The function $f(\cdot)$ is concave and increasing in $\hat{I}$. Further, the output of consumption per unit of endowment invested $g(\hat{I})$ obeys the following restriction:

$$g(\hat{I}) = f(\hat{I})/\hat{I} \geq 1 \tag{4.1}$$

That is, the average gross return to investment in the alternative technology is always greater than or equal to one (in the relevant range).

Assume that there exists a fixed number of firms which each independently operate the technology. For convenience, normalize the number of firms at unity.[24] The firm's economic decisions are trivial. It simply accepts endowment and issues securities which are claims to the subsequent yield. It uses the endowment to produce consumption output two periods later and then distributes all the revenues to its creditors, based on their respective percentage contributions to the investment. The important point to note is that, because its production activity is publicly observable, the firm can directly issue securities to any other agent in the economy, without the need for a monitoring intermediary.

Since there is no moral hazard problem, it is also true that the securities issued by the firm may have returns contingent on its earnings, if they are random. This potential dependence on earnings is in practice an important distinction between equity-like securities and (adequately-backed) demand deposits issued by banks. In the present analysis, however, we will avoid dealing with random security yields by the expedient of assuming that the alternative technology is purely deterministic. We make this assumption for two reasons: First, this approach results in considerable simplification, without affecting the nature of the main results. Second, as will be seen in a moment, in our model determinacy

[24] It may be useful to think of this single firm as being owned in common by members of the currently-investing generation.

in security returns allows for the creation of security-backed assets that are perfect substitutes for bank demand deposits in consumers' portfolios. This perfect substitutability between the principal financial assets available to savers will permit us to shift the focus of the analysis from traditional issues concerning the special role of bank liabilities to the question that most concerns us here: the special role of bank-intermediated credit.[25]

As we have noted, the public observability of the alternative technology implies that there is no barrier to the direct issuance of firm securities to consumers. There remains the problem, however, that the security is a claim to an investment that pays off only after two periods, while a fraction $\alpha$ of consumers will want to consume one period after investment. There are a number of possible institutional arrangements that could address this problem. For example, individual consumers could combine purchases of securities with the storage of endowment. After the revelation of types, Type I's would be willing to trade their shares to Type II's (say, at a prespecified price) in exchange for the Type II agents' storage. Type II's would then consume the proceeds of all the firm's investments in the second period of life. A similar result could be obtained if the firms stored as well as invested in the alternative technology.

A difficulty with purely intra-generational solutions to the liquidity problem is that they imply the perpetual existence of storage in the economy, which may be inefficient; a similar problem would arise in the banking sector, if bankers only lived two periods. In symmetry with our assumptions about the banking sector, therefore, we introduce a new class of infinitely-lived agents, capable of trading with multiple generations. These new agents are called brokers. Brokers intermediate funds between households and firms, but they do not perform any monitoring. Rather, their function is to pool liquidity risk. Brokers issue liabilities to newly born consumers in exchange for endowment; they invest this endowment in storage and firm securities. Because there is no uncertainty in firm returns, without loss of generality we can assume that brokers' liabilities are in the form of demand deposits, i.e., broker liabilities and bank liabilities will be perfect substitutes.[26]

[25] The emphasis of most analyses on bank liabilities rather than bank assets derives from the traditional concern with the quantity of the medium of exchange. For further discussion, see Section 5.

[26] Alternatively, brokers could set themselves up as mutual funds that pay a first-period dividend of consumption and permit an ex-dividend trading of shares (consumption goods

We assume that brokers have the same preferences as bankers, except that they do not have access to a monitoring technology, nor do they receive an endowment each period. Thus, they will not invest in the uncertain, monitoring-intensive projects used by banks. The issue of brokers' risk preferences is irrelevant, since their only option is to acquire assets with certain returns. As with bankers before, we normalize the number of brokers at unity.

So that brokers may have a non-trivial economic role in the model, we will assume banks do not have access to the alternative technology. That is, banks may neither acquire firm securities directly, nor may they acquire them indirectly by buying deposits from brokers. (This may be thought of as resulting from a legal restriction that separates commercial and investment banking. Without this assumption, banks would intermediate all investment in the economy.) It turns out that this assumption has only minor effects on the real equilibrium allocation, e.g., on the distribution of resources between the two technologies; and, in fact, it makes the calculation of the equilibrium marginally more difficult. The advantage of preserving the distinction between banking and brokerage is that it will make it easier to use the model to study phenomena such as reserve requirements and interest rate ceilings that affect the banking and non-banking sectors differentially. Also, by restricting banks away from the alternative technology, we gain the expositional advantage of not having here to re-solve the bank's optimization problem to include the possibility of making alternative-sector investments.

Given the prohibition against bank investment in the alternative technology and the argument that consumers will not buy firm securities directly, it follows that broker purchases of firm securities each period will equal the total investment in the alternative technology, $\hat{I}_t$. Further, since brokers have no capital of their own, the endowment available to them for investment or storage each period is precisely equal to the number of deposits they issue, $\hat{D}_t$. Let $\hat{S}_t$ the storage by the broker at $t$. The broker then faces the following resource constraint in each period:

$$\hat{I}_t + \hat{S}_t = \hat{D}_t \tag{4.2}$$

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for stock) among their investors. With no uncertainty (in either investment returns or the rate of depositor withdrawal), this arrangement is isomorphic to the issuance of demand deposits.

Let: $\hat{\pi}_t$ be the flow of profits accruing to the broker each period; $\hat{R}_t$ the dividend at $t$ per unit of investment made at $t-2$, paid by the firm; and $\hat{r}_t^1$ and $\hat{r}_t^2$ the rate of return to households on broker deposits acquired at $t$ and held for one and two periods respectively. The flow of profits to the broker is

$$\hat{\pi}_t = \hat{R}_t \hat{I}_{t-2} + \hat{S}_{t-1} - \alpha \hat{r}_{t-1}^1 \hat{D}_{t-1} - (1-\alpha)\hat{r}_{t-2}^2 \hat{D}_{t-2} \tag{4.3}$$

The first two terms on the right hand side reflect the broker's revenues from securities purchases and storage, while the last two terms reflect his net obligations.

Note that we are asserting that brokers, as well as bankers, can expect with certainty to have to redeem, in period $t$, a fraction $\alpha$ of the deposits made at $t-1$ and a fraction $1-\alpha$ of those made at $t-2$. As was discussed above in the context of an economy with only banking, this assertion is legitimate either if we assume that each broker (and banker) has depositors representable by a measurable portion of the real line; or, alternatively, if we allow brokers and bankers to co-insure each other against withdrawal risk.[27]

The broker must be able to pay the returns promised to depositors. Thus the following non-negativity constraint on profits restricts the broker's decisions:

$$\hat{\pi}_t \geq 0. \tag{4.4}$$

This restriction is analogous to the liquidity constraint (2.6) faced by bankers. An important difference is that because the broker's earnings are certain and he faces no informational problems, he needs only to ensure that his actual profits are non-negative. In contrast, the banker (because of the agency problem created by asymmetric information and uncertain project outcomes) must satisfy his liquidity constraint even under the worst possible portfolio outcomes.

Since the brokers have the same preferences as bankers, the choice problem facing each broker is:

$$\max E_0 \left\{ \sum_{t=1}^{\infty} \beta^t \hat{\pi}_t \right\} \tag{4.5}$$

[27] Perfect insurance is possible here because of our assumption that there is no aggregate liquidity risk. It should also be noted that these various intermediaries need not enter formal insurance contracts. In this case, a "federal funds" market could perfectly perform the insurance function.

subject to (4.1) through (4.4). Let $\beta^{t+1}\hat{\lambda}_t$ be the multiplier associated with the non-negativity constraint on the broker's profits. Then the first order necessary conditions for investments in firms and in storage are (after using (4.2) to eliminate $\hat{D}$ from the problem), respectively

$$\beta\hat{R}_t(1+\hat{\lambda}_{t+1}) \geq [\alpha\hat{r}_t^1(1+\hat{\lambda}_t) + \beta(1-\alpha)\hat{r}_t^2(1+\hat{\lambda}_{t+1})] \tag{4.6}$$

$$(1+\hat{\lambda}_t) \geq [\alpha\hat{r}_t^1(1+\hat{\lambda}_t) + \beta(1-\alpha)\hat{r}_t^2(1+\hat{\lambda}_{t+1})] \tag{4.7}$$

The left sides of (4.6) and (4.7) are the marginal benefits from purchasing a security (in units of endowment) and from storage, respectively. The right side of each equation is the value of the additional obligation to depositors implied by accepting a unit of endowment. Equation (4.6) holds with equality in equilibrium, while (4.7) does so only if brokers are storing.

4b. *Equilibrium with Brokers and Banks*

We now describe the construction of general equilibrium in a model with both the banking and non-banking sectors. The objective is to determine the allocation between investment in the random two-period technology (which requires bank monitoring) and the alternative technology (which is costlessly observable). We will use the term "size of the banking sector" to mean the amount of investment (net of the bankers' endowments) in the illiquid random technology, in order to focus on the investment flow which is dependent on banks.

Begin by noting that, in equilibrium, the sum of deposits that households make with banks and brokers must equal the aggregate consumer endowment:[28]

$$W = D_t + \hat{D}_t. \tag{4.8}$$

Arbitrage ensures that banks and brokers must offer competitive returns. We have

*Lemma 3.* If depositors hold positive quantities of both broker and bank demand deposits, then the competing deposit contracts must be identical. That is,

$$r_t^1 = \hat{r}_t^1 \tag{4.9}$$

[28] For reasons discussed above, we can neglect the possibility that consumers will undertake storage or invest in firms on their own.

$$r_t^2 = \hat{r}_t^2 \tag{4.10}$$

PROOF: (Sketch) First note that banks are indifferent among demand deposit contracts $(r^1, r^2)$ that satisfy the arbitrage condition (2.13). Similarly, brokers are indifferent among demand deposit contracts $(\hat{r}^1, \hat{r}^2)$ which satisfy the analogous condition (4.6), which holds with equality in equilibrium. Thus, as before, the demand deposit contracts which survive in the market will be those that maximize the consumer's utility subject to the two arbitrage constraints.

When the consumer's utility maximization problem is solved (with the constraints imposed), the following results arise: (1) If consumers hold both broker and bank demand deposits in equilibrium, then the return on the broker's illiquid project initiated in period $t$ must equal the bank time deposit rate in $t$. Otherwise, one sector or the other could offer a dominant deposit contract and consumers would not hold both types of deposits. (2) In equilibrium, the marginal rate of transformation between the first and second–period demand deposit rates must be the same in the brokerage and banking sectors. (3) If an individual consumer holds both broker and bank demand deposits, then the allocation of his endowment between the two types of deposits is indeterminate.

Result (3) implies that a consumer who holds both types of deposits should be indifferent between a portfolio consisting only of bank deposits and one consisting only of broker deposits. From (1) and (2), these two portfolios should offer the same return stream. We know from Section 3 that the demand deposit contract preferred by a consumer with a homogeneous portfolio is unique. Thus the deposit rates must be identical in the two sectors. ∎

The rates of return that brokers can offer will vary inversely with aggregate level of securities they acquire (that is, the aggregate amount of investment in the alternative technology), which in turn depends on the amount of deposits they receive. Accordingly, the dividend payout at $t$ per unit of endowment invested at $t-2$, $\hat{R}_t$, is given by

$$\hat{R}_t = g(\hat{I}_{t-2}) = f(\hat{I}_{t-2})/\hat{I}_{t-2} \tag{4.11}$$

Clearly $\hat{R}_t$ is decreasing in $\hat{I}$, due to the concavity of the production function $f(\cdot)$. Further, as stated in the discussion in the proof of Lemma 3, it must be the case that the safe two–period returns in the brokerage and banking sectors must be equal[29]:

$$\hat{R}_t = r_{t-2} \tag{4.12}$$

[29] Recall that the timing conventions are such that $\hat{R}_t$ and $r_{t-2}$ are both returns to investments initiated in $t-2$.

Thus, from (4.12), it follows that

$$g(\hat{I}_t) = r_t \tag{4.13}$$

Equation (4.13) suggests the following scenario: a fall (rise) in the bank time deposit rate will lead to an inflow (outflow) of resources to brokers, who in turn purchase (sell) securities until that rate of return to investment in the alternative technology is again equalized with $r_t$. The non-negativity constraint on profits ( i.e., the liquidity constraint) determines whether brokers will have to set aside for storage some of their funds received from depositors.

4c. *The Steady State*

The steady state in the model with brokers and bankers is analogous to the earlier case without brokers, firms, or the alternative technology. The main difference is that now the supply of bank deposits is endogenous, since resources may flow between banking sector investments and the alternative technology. From (4.11) and (4.12), we know that investment in the latter sector varies inversely with the time deposit rate offered by banks. As before, the time deposit rate, and hence the real allocation, is highly sensitive to the quantity of bank capital and to the lower bound of the support of the returns to the bank's illiquid projects.

*Proposition 4*: Let the function $\hat{I}(r)$ equal $g^{-1}(r)$, as defined in (4.13). $\hat{I}(r)$ is the level of investment in the alternative technology in equilibrium, as a function of the bank time deposit rate. Further, define the function

$$\phi(r) = [r(W - \hat{I}(r)) + xR^{\ell}\hat{I}(r)]/W \tag{4.14}$$

$\phi(r)$ is positive and monotone increasing in $r$. Then if the quantity $xR^{\ell}(1 + W_b/W)$ is:

(i) $> \phi(\overline{R}/(1+\delta))$, then in the steady state both banks and brokers invest only in illiquid (two–period) projects; there is no storage. The time deposit rate equals $\overline{R}/(1+\delta)$. The allocation of investment between the banking and brokerage sectors is defined by the following equations:

$$W + W_b = (1+\delta)I + \hat{I} \tag{4.15}$$

$$g(\hat{I}) = \overline{R}/(1+\delta) \tag{4.16}$$

(ii) $\leq \phi(\overline{R}/(1+\delta))$ but $\geq \phi(1/\beta)$, then again in the steady state brokers and banks invest only in illiquid projects. However, now the time deposit rate and the allocation of investment are defined by the following relations:

$$W + W_b = (1+\delta)I + \hat{I} \tag{4.17}$$

$$xR^{\ell}(1 + W_b/W) = \phi(r) \tag{4.18}$$

$$g(\hat{I}) = r \tag{4.19}$$

(iii) $< \phi(1/\beta)$, then in the steady state there will be investment in the liquid asset (storage). The time deposit rate equals $1/\beta$. The level of investment in the random two-period technology of banks is indeterminate. The following relations restrict the equilibrium:

$$W + W_b = (1+\delta)I + \hat{I} + S + \hat{S} \tag{4.20}$$

$$R^{\ell}I + S = (W - \hat{I} - \hat{S})/(\beta x(1+\delta)) \tag{4.21}$$

$$g(\hat{I}) = 1/\beta \tag{4.22}$$

$$\frac{1}{\beta}\hat{I} + \hat{S} \geq (\hat{I} + \hat{S})/(\beta x) \tag{4.23}$$

PROOF: See the appendix. ∎

Proposition 4 says that the nature of the steady state when there are brokers and banks hinges on the magnitude of a quantity that is proportional to $R^{\ell}(1 + W_b/W)$. If the minimum return to bank investments $R^{\ell}$ and the dividend from bank capital relative to consumer endowment $W_b/W$ are very high, then in the steady state there is no storage in the economy, and the time deposit rate and the amount of resources devoted to the banking sector are at a maximum. For intermediate values of $R^{\ell}$ and $W_b/W$ there is still no steady-state storage, but the bankers' time deposit rate and deposits received are somewhat less. Finally, at low levels of $R^{\ell}$ and $W_b$, there is perpetual storage, time deposit rates are at their minimum level of $1/\beta$, and the amount of resources diverted away from banks into the alternative technology is at a maximum.

For very low levels of $R^\ell$ and/or $W_b/W$ it is also possible that, as in the model without the alternative technology, there may be no banking in the steady state. Analogous to Proposition 2 above, we have

*Proposition 5.* Let $\hat{D}^*$ be the maximum level of deposits that brokers will accept when $r = 1/\beta$ (i.e., the quantity of deposits that causes the liquidity constraint (4.23) to be binding). If (a) $xR^\ell(1 + W_b/W) < \phi(1/\beta)$, and (b) $\frac{W_b}{W-\hat{D}^*} < \frac{1+\delta-R^\ell}{R^\ell-\delta}\frac{\rho(1-\alpha)(1-\beta)}{\beta(\alpha+\rho(1-\alpha))}$, then in the steady state banks will not invest depositor funds in the risky two–period assets.

PROOF: By reasoning analogous to that of the proof of Proposition 2, it is easy to verify that if (a) and (b) hold, the steady state level of bank investment in the illiquid project $I$ would be less than $W_b$. Hence banks will not accept deposits and instead will simply invest their own endowment in the two–period technology. As in the earlier case, the level of bank capital in insufficient to provide the necessary insurance. ▮

4d. *Dynamic Stability*

Finally, we turn to a brief discussion of the dynamic stability of the model with brokers and bankers. It is possible to derive an expression for the dynamic behavior of investment in the random illiquid technology, analogous to (3.26):

$$I_t = [R^\ell I_{t-1} + W_b - \frac{(1-\alpha)\rho r_{t-1}}{\alpha+\rho(1-\alpha)}(W - \hat{D}_{t-1}) + \frac{(1-\alpha)\rho}{\alpha+\rho(1-\alpha)}(W - \hat{D}_t)](1+\delta)^{-1} \quad (4.24)$$

where the level of deposits in the brokerage sector $\hat{D}_t$ varies inversely with $r$, for reasons discussed earlier. (4.24) differs from (3.26) only in that the level of deposits in the banking sector is now endogenous.

*Proposition 6.* The model with brokers and bankers is dynamically stable; i.e., it always converges to a steady state as defined by Proposition 3.

PROOF: When the steady state involves no storage, the reasoning is virtually the same as in the analogous part of Proposition 3. (It is helpful to recognize that $\hat{D}$ will vary inversely with $r$.) When there is storage in the steady state, the time deposit rate jumps immediately to $1/\beta$, for reasons discussed in Proposition 2. Hence the level of investment in the alternative technology moves instantly to its steady state value. What happens to $I$, $S$, and $\hat{S}$ is within certain bounds indeterminate, for reasons discussed in Proposition 4. ▮

## 5. *Some Applications*

Because the model of this paper is somewhat unusual, we have devoted much space to the details of its operation. The cost of this is that, in the present paper, we will not be able to develop completely the model's applications. The potential applications, however, appear to be varied and important. Here we will just briefly describe some of the significant possibilities:

*The relationship of financial stability to macroeconomic performance.* In a descriptive/historical paper, Bernanke argued that the collapse of the financial system in the 1930's, and the resulting loss of intermediary services, played an important role in the general decline in output and employment. One also hears considerable conjecture, in the news media or informally from colleagues, that the precariousness of international or domestic credit markets poses a significant threat to the contemporary economy. Yet there has been little substantive economic analysis of how or whether a financial collapse could have large real effects, or of how such effects could be averted.

The model of our paper would seem to be a suitable framework for such an analysis. We have already shown, for example, that the quantity of bank capital and the minimum gross return to bank assets play a key role in determining the size of the banking system and the equilibrium quantity of bank-intermediated credit. A financial collapse[30] would emerge if there were either a large deterioration of bank capital or a significantly unfavorable change in the support of the distribution of bank investment returns. As follows from the analysis of Sections 3 and 4, either of these occurrences would force a contraction of bank liabilities and bank investment, with resources being diverted to the alternative sector.[31] As actually happened in the 1930's, the cost of funds to firms in the "safe" alternative sector would fall, while monitoring-intensive projects which rely on bank credit might not be able to obtain funds at all. Overall, the marginal efficiency of investment would fall. With endogenous

[30] A financial collapse is here to be thought of as a sharp reduction in the size of the intermediary sector; it does not necessarily entail a bank run.

[31] Once changes in $W_b$ or $R^\ell$ are admitted, the question arises as to whether deposit contracts will be written contingent on the values of these variables. The answer to this question is relevant to whether existing depositors will receive their promised payouts and, in some variants of this model, to whether bank runs occur. However, the ultimate effects of changes in $W_b$ and $R^\ell$ on the real allocation of resources, with which we are most concerned, is essentially independent of whether deposit contracts are contingent.

labor supply in place of the fixed consumer endowments assumed in the present version of the model, the decline in safe rates of return might have second-round effects on output, as agents find that the return to working is lower.

Our model is currently not rich enough to provide an endogenous explanation of why bank capital or the return distribution might change unfavorably. However, it is conceivable that this analysis might be extended to a yet more detailed setting, in which these variables are related to aggregate economic activity (as was clearly the case, e.g., in the Great Depression). This extension would show how "fundamental" factors can explain major contractions in banking. Note that this is in contrast to the Diamond–Dybvig approach to the study of financial collapse, in which market psychology ("sunspots") is critical. However, with a bit of modification, our model (which has incorporated much of the Diamond–Dybvig structure) could also be used to analyze financial crises which are caused by sunspot-induced bank runs. Presumably, again the principal effects would be the contraction of bank liabilities and bank credit, and the diversion of resources to the alternative sector.

Another possible modification of the model that would permit an interesting analysis of bank runs and bank failures would be the inclusion of bank "bonding" in the demand deposit contract, as discussed in Section 2 above (cf. Diamond). With bonding, incentive-compatibility would no longer require that the bank be able to meet its obligations in all contingencies. Thus, periodic bank failures would naturally occur. Inside information about pending failures could again generate "fundamentally-based" runs (cf. Jacklin). Again, such runs would have real allocative effects.

*The effects of banking regulation and de-regulation.* There is currently much deregulation of the banking system, much of it in the name of microeconomic efficiency. However, most of the original regulation was imposed on macroeconomic, not microeconomic, grounds. How does banking regulation relate to the performance of the macroeconomy? The discussion of financial stability above suggests that certain regulations, such as bank capital requirements, deposit insurance, and the necessary monitoring that deposit insurance brings, may be macroeconomically justified. Some other bank regulations, such as interest rate ceilings, probably are (were) not justified, since they distort the allocation of investment without visibly contributing to financial stability. [32] Our model would be useful, for example, in studying the steady-state and dynamic effects of interest rate ceilings. While this analysis might involve some complexities, we would expect many of the qualitative implications of binding rate ceilings to resemble those of inadequate bank capital. In particular, it should be possible to generate in our model the "disintermediation" process (as occurred in the U.S. in 1966, 1973, etc.), in which the restriction of bank deposit rates below equilibrium levels causes a reallocation from bank to non-bank investments. Since disintermediation lowers the return to savers in the economy, it seems clear that this phenomenon should have real macroeconomic effects.

*The monetary transmission mechanism.* The means by which central bank policy affects the economy, if it indeed it does affect the economy, is one of the basic questions of macroeconomics. Researchers have addressed this question in a number of ways. The traditional, and most familiar, analysis of central bank policy focuses on the quantity of the medium of exchange, arguing that the central bank can affect the economy only insofar as it affects this quantity. The liability side of the bank balance sheet receives special attention in this approach, because demand deposits are a large part of conventionally-defined money.

We certainly do not wish to claim that the quantity of the medium of exchange is without significance. However, as originally argued by Gurley and Shaw, the traditional approach is less relevant, the greater the number of substitutes for conventionally-defined money in consumers' portfolios.[33] An alternative to the traditional approach, and the one taken by this paper, is to take into account bank assets as well as bank liabilities: In particular, our model eliminates any "specialness" of bank liabilities in order to focus on the possible non-substitutability of bank and non-bank credit. (Our paper is thus in the spirit of, e.g., Blinder and Stiglitz.) In this alternative framework, "monetary policy" (e.g., the manipulation of reserve requirements) matters to real activity because it affects the extent of financial intermediation, not primarily because it affects the quantity of the medium of exchange. This distinction may be of practical importance to the conduct of

[32] For an opposing view, see Bruce Smith (1984).

[33] For example, Hester (1981) argues that the numerous money substitutes that have resulted from ongoing financial innovation have made dubious the notion that regulating monetary aggregates is useful or even feasible.

monetary policy; for example, in the choice of intermediate targets.

It should be pointed out that there are several ways to introduce monetary policy into our framework, and that the conclusions which are drawn may depend heavily on the chosen specification. A particularly important modelling decision is whether to treat the central bank as controlling the nominal or the real quantity of bank reserves. Nominal reserve control means that the central bank issues a fixed number of "dollars" to be held as legal reserves against nominal quantities of deposits. In this case, changes in the aggregate price level can make the existing quantity of reserves consistent with any level of real deposits or loans. Under these circumstances, open-market operations (for example) will have no significant real effects.[34] Alternatively, under a regime of real reserve control, the central bank is to be thought of as issuing a fixed number of "permits", which are required to be held for a bank to accept a unit of deposit measured in *real* (resource) terms. Real reserve control may be the appropriate assumption, for example, in a Keynesian setting, or when deposits and loans are issued in nominal terms and are not indexed; it is also isomorphic to the policy of direct control of bank credit, which has been experienced in recent episodes in the U.S. and U.K. With real reserve control, open-market operations will affect the real size of the banking sector and, as should be obvious by now, will change real allocations in the economy.[35]

Ultimately, whether monetary policy works primarily through bank assets or bank liabilities is an empirical issue. The early empirical returns have not been particularly favorable to the bank credit story; for example, Stephen King (1984) found stronger reduced-form correlations between demand deposits and output than between commercial and industrial loans made by banks and output. However, because both demand deposits and bank credit presumably have large endogenous components (see R. King and Plosser (1984)),

[34] Changes in reserve requirements will still affect real allocations, however.

[35] A possibly disturbing implication of our model with real reserve control is that a reduction of reserves by the central bank will, by re-directing resources from the banking to the non-banking sector, *lower* interest rates in the non-banking sector. However, this result is to some degree artificial, being generated by our assumptions that endowments and saving are fixed, and that the fall in investment in the banking sector does not affect the supply of inputs or the demand for output in the non-banking sector. A related implication of the model, which we believe is more robust and more realistic, is that contractionary open-market operations will increase the differential in the expected return to investment between the banking and non-banking sectors.

this finding does not settle definitively how an exogenous shock to deposits or credit will affect the economy. Moreover, Stephen King only considers commercial banks; our analysis suggests that a broader set of financial intermediaries might be relevant. In any case, permitting a sharper formulation of hypotheses about the transmission mechanism is an important goal of the present line of research.

## 6. *Conclusion*

This paper is the beginning of what may be an extended research program, in which we will try to gain a better understanding of the role of financial intermediaries in the determination of macroeconomic equilibrium. Our work is similar to much recent research on banking in that we are attempting to move away from the conception of financial institutions as a "veil", towards a view which acknowledges that these institutions provide important services to the economy. This paper differs from much previous research, however, in conducting the analysis in general rather than partial equilibrium; thus we are able to relate the performance of the banking sector to aggregate variables such as interest rates and the sectoral distribution of investment. In future work we hope to extend the general equilibrium aspect of this or similar models even further—to include, for example, the endogenous determination of labor supply and of the supply of bank capital.

We will close by raising a question that has occurred to us, as follows: Whatever the historical relevance of this analysis, is it not possible that the widespread innovation in financial markets currently taking place will make this paper irrelevant to the study of the modern economy? Since our analysis relies heavily on the assumption that intermediary and non–intermediary assets are imperfectly substitutable, it is particularly important to ask whether innovations such as improved information technology and new financial instruments will eliminate over time the special roles played by intermediaries in certain credit markets. For example, will the introduction of instruments like mortgage–backed securities eventually decouple completely the fortunes of traditional mortgage lenders and of the construction industry? If so, the "bank credit" approach to the monetary transmission mechanism, for example, will no longer be of practical interest.

This question is too big to address in a really satisfactory way here, but we will essay the following: The current perception that financial innovation is fundamentally changing the nature of the role that intermediaries play in credit markets is, in our view, somewhat overstated. Consider the mortgage–backed securities currently being issued by banks and savings and loans, for example. First, the existence of these securities does not imply that the agency costs of intermediation are somehow being overcome: The mortgages used as backing for these bonds are all insured against default, primarily by the Federal government.[36] Thus, as with the introduction of deposit insurance, the most significant real change is that the responsibility for monitoring intermediary actions has devolved from intermediary creditors to the government. Second, these securities do not permit the complete separation of mortgage origination and mortgage ownership, as is sometimes made out. Mortgage bonds are considered good risks because they are typically backed by "mature" mortgages for which collateral averages from 125% to 160% of face value.[37] From the point of view of the purchasers of these securities, this high rate of collateralization performs a buffer role and thus substitutes for bank capital. However, since most loans made by intermediaries are not so highly collateralized, at least during the period following issuance, the potential for decoupling loan issuance and ownership is necessarily limited. (Indeed, in order to sell off loans, intermediaries have appeared willing either explicitly or implicitly to guarantee them against default.[38]) Furthermore, to the extent that intermediaries commit their most highly collateralized loans as backing to securities, the agency problem with respect to regular depositors (or the deposit insurance agency) is exacerbated, and their need for capital on that account (at least under appropriate regulation) is increased. Thus mortgage–backed securities, although a new source of funds for mortgage intermediaries, do not eliminate the agency costs of intermediation or change the basic economics of the situation.[39]

It is at least possible, we conclude, that the analysis of this paper will remain directly relevant despite the sweeping changes occurring in financial markets. If not, then at least the paper may prove helpful in understanding the effects of these changes as they occur.

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[36] Dennis(1983, p. 28).

[37] *Ibid.*

[38] See the *Economist*, May 11, 1985. (We thank Stephen King for this reference.)

[39] For intermediaries other than mortgage lenders, there would seem to be even less scope for the development of secondary markets, since the collateral backing the typical non–mortgage intermediary asset is usually more difficult to value than is real estate.

## Appendix. Proofs of some propositions

*Proof of Proposition 3.*

We consider in turn the three possible cases defined in Proposition 1.

*Case (i).* From Proposition 1, in this case banks only invest in illiquid projects in the steady state and the time deposit rate equals $\overline{R}/(1+\delta)$. Define $\tilde{I}_t$ by:

$$\tilde{I}_t = [R^\ell \tilde{I}_{t-1} + W_b - \frac{(1-\alpha)\rho(\tilde{r}-1)}{\alpha+\rho(1-\alpha)} W]/(1+\delta) \quad (A.1)$$

with $\tilde{I}_0 = I_0$ and where $\tilde{r} = \frac{\overline{R}}{(1+\delta)}$. It is clear from (3.25), (3.26), and (3.28) that $\tilde{I}_t \leq I_t$ for all $t$, but that the steady states of the difference equations for $\tilde{I}$ and $I$ are identical (since $r = \tilde{r}$ in the steady state). Thus if $\tilde{I}$ converges, so does $I$. Since the coefficient of $\tilde{I}_{t-1}$ in (A.1) is between zero and unity, $\tilde{I}$ converges toward its steady state. The steady state of (A.1) (and thus also of (3.26)) exceeds $(W + W_b)/(1+\delta)$. $\tilde{I}$ thus increases until it absorbs all of the economy's endowment. The same behavior must therefore be exhibited by $I$.

Correspondingly, the steady state value of the shadow price $\lambda$ in this case must be zero. The terminal condition requires that the initial value of $\lambda$ be below the staeady state value $\overline{\lambda}$, since the difference equation for $\lambda$ is unstable.

*Case (ii).* In this case, according to Proposition 1, in the steady state banks only invest in the illiquid asset and the time deposit rate equals $xR^\ell(1 + W_b/W)$. The proof of convergence is identical to the previous case, except now set $\tilde{r} = xR^\ell(1 + W_b/W)$ in the definition of $\tilde{I}$. (Note that, from (3.26), (3.27), and the terminal condition that $\lambda = 0$, that $r_t$ is always less than $\tilde{r}$; hence $\tilde{I} \leq I$.) In this case, the steady states of the difference equations for $\tilde{I}$ and $I$ are both equal to $W + W_b$, which is exactly the number of illiquid projects that are funded when all resources are devoted to the illiquid asset.

*Case (iii).* In this case, $xR^\ell(1 + W_b/W) < 1/\beta$. Assume also that $W_b/W$ satisfies condition (b) from Proposition 2, so that banking arises. From Proposition 1, in this case in the steady state there is investment in the liquid asset and the time deposit rate equals $1/\beta$. Since storage takes place perpetually, the steady state value of the shadow price $\lambda$ is positive. Since the difference equation for $\lambda$ (3.27) is unstable, $\lambda$ must jump to its steady state value in the initial period. By the same logic used in the proof of Lemma 2, it follows that the time deposit rate also jumps immediately to its steady state value $1/\beta$. The difference equation for $I$ can now be written

$$I_t = [R^\ell I_{t-1} + W_b - \frac{(1-\alpha)\rho(r-1)}{\alpha+\rho(1-\alpha)} W]/(1+\delta) \tag{A.2}$$

where $r = 1/\beta$. (A.2) is a stable difference equation.

*Proof of Proposition 4.*

The reasoning follows closely the proof of Proposition 1. It is helpful to recall, from Lemma 2, that the time deposit rate lies within the closed interval $[1/\beta, \overline{R}/(1+\delta)]$.

In the steady state without storage, bankers must be able to satisfy their liquidity constraints with $S = 0$. Therefore, from (2.6) and (4.8), the following condition must hold:

$$R^\ell I \geq (\alpha r^1 + (1-\alpha) r^2)(W - \hat{I}) \tag{A.3}$$

Note that $W - \hat{I}$ is the quantity of bank deposits. Substituting (3.6), (3.8), and (4.15) into (A.3), we obtain

$$R^\ell (W + W_b - \hat{I}) \geq r(W - \hat{I})/x \tag{A.4}$$

where $1/\beta \leq r \leq \overline{R}/(1+\delta)$. Rearranging (A.4) yields

$$xR^\ell(1 + W_b/W) \geq [r(W - \hat{I}) + xR^\ell \hat{I}]/W \tag{A.5}$$

Since $\hat{I}$ is an inverse function of the deposit rate, we can write (A.5) as

$$xR^\ell(1 + W_b/W) \geq \phi(r) \tag{A.6}$$

where the function $\phi(\cdot)$ is as defined above.

When the left side of (A.6) strictly exceeds $\phi(\overline{R}/(1+\delta))$, as in case (i), it follows that the liquidity constraint for banks is not binding in the steady state. Further, the steady–state liquidity constraint for brokers, which can be written generally as

$$r\hat{I} + \hat{S} \geq r(\hat{I} + \hat{S})/(x(1+\delta)) \tag{A.7}$$

is always non–binding at $\hat{S} = 0$ for any admissible value of $r$. (Recall that $x(1+\delta) > 1$.) Hence there is no storage in the economy. The time deposit rate adjusts to equate the expected marginal benefits and costs from investing in the various illiquid projects. As in case (i) of Proposition 1, (2.15) holds with equality, which implies $r = \overline{R}/(1+\delta)$.

If, however, the left side of (A.6) is less than $\phi(\overline{R}/(1+\delta))$, the bank's liquidity constraint will be violated if $r = \overline{R}/(1+\delta)$. In this case the time deposit rate is determined by the liquidity constraint (A.6), given that the solution for $r$ is greater than or equal to $1/\beta$. As in case (ii) of Proposition 1, banks do not invest in illiquid assets, since they can satisfy their liquidity constraints without doing so. Even though the expected return to investing in the illiquid project exceeds the time deposit rate in equilibrium, banks are limited from further investment by liquidity considerations. Also, again brokers do not need to store.

When $xR^{\ell}(1+W_b/W) < \phi(1/\beta)$, banks must invest in the liquid asset (store) in the steady state in order to satisfy the liquidity constraint, since $r$ may not fall below $1/\beta$. Indeed $r$ will equal $1/\beta$ in this case, according to Lemma 2. It follows directly that in order for banks to satisfy the liquidity constraint in this case, equation (4.21) must hold.

In this case, unlike cases (i) and (ii), brokers may invest in liquid assets as well (although they need not). This is because, when the time deposit rate equal $1/\beta$, it follows from the broker's first order conditions that he is indifferent between investing in the two–period alternative technology and storing, so long as the liquidity constraint (4.23) is not violated. (It will not be violated when $\hat{S} = 0$.)

The real allocation, however, is not completely determined in case (iii). It is true that investment in the alternative technology is fixed by the condition that the real return on this investment equal $1/\beta$ (equation (4.22)). However, the exact breakdown between the two sectors of investment in the liquid asset, and the amount of investment by banks in their illiquid asset, is indeterminate. At one extreme, there is no storage by brokers. In this case, bankers adjust $I$ and $S$ to satisfy their respective liquidity constraints. At the other extreme, bankers do not store; instead, they reduce the amount of deposits to the point where they can satisfy the liquidity constraint without investing in liquid assets. Brokers accept these deposits and invest the funds in liquid assets, provided they do not violate their own liquidity constraint. It may be verified that, for the case where $r = 1/\beta$, bank investment in the two–period asset is at a minimum in the former extreme case, and at a maximum in the latter.

Figure 1

Relationship Between the Steady State Time Deposit Rate $r$ and the Ratio of Bank to Household Endowment $W_b/W$

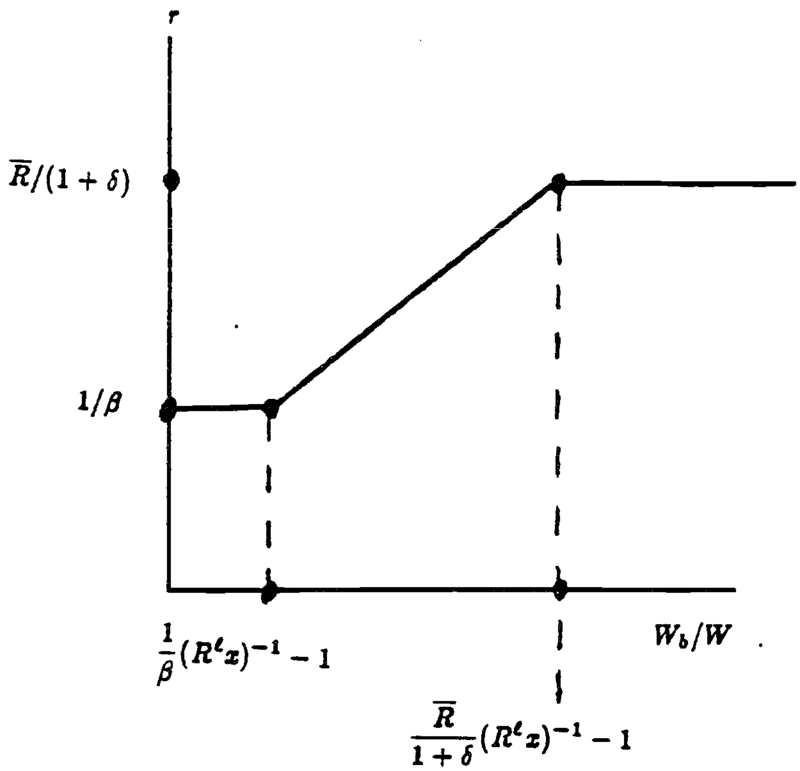
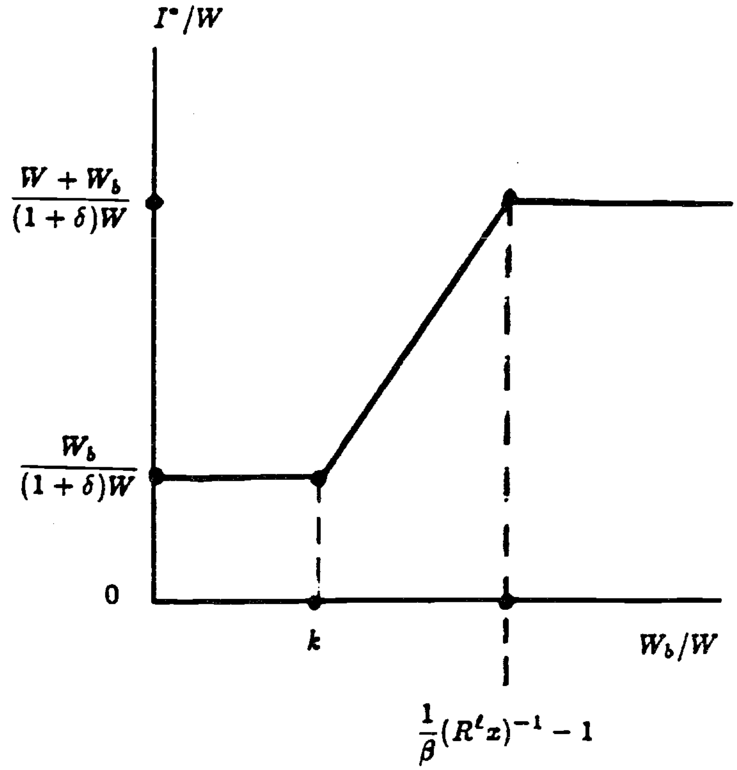


**Figure 2**

Relationship Between the Steady State Ratio of Investment to Household Endowment $I^*/W$ and the Ratio of Bank to Household Endowment $W_b/W$




$$k = \frac{(1+\delta - R^\ell)}{(R^\ell - \delta)} \frac{\rho(1-\alpha)(1-\beta)}{\beta(\alpha + \rho(1-\alpha))}$$

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