Journal of Banking and Finance 4 (1980) 335–344. © North-Holland Publishing Company

A MODEL OF RESERVES, BANK RUNS, AND DEPOSIT INSURANCE*

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Received June 1979, final version March 1980

A model is presented in which demand deposits backed by fractional currency reserves and public insurance can be beneficial. The model uses Samuelson's pure consumption-loans model. The case for demand deposits, reserves, and deposit insurance rests on costs of illiquidity and incomplete information. The effect of deposit insurance depends upon how, and at what cost, the government meets its insurer's obligation — something which is not specified in practice. It remains possible that demand deposits and deposit insurance are a distortion, and reserve requirements serve only to limit the size of this distortion.

1. Introduction

In an earlier paper, Bryant and Wallace (1980), monetary policy in a world of reserve requirements and deposit insurance is discussed. However, in that model deposit insurance is a distortion and reserve requirements serve only to limit the size of this distortion. This paper presents a model in which both deposit insurance and reserves play a useful role in the economy. In the earlier paper there was no borrowing and lending, but there was a risky storage technology. In this paper, largely to increase the variety of available models, there is borrowing and lending rather than risky storage of an asset.

To generate a model of useful deposit insurance, it is first necessary to generate deposit liabilities backed by risky assets. Once one has done so, the possibility of some form of bank run immediately follows. The model is one of non-price rationing. The inefficiency of non-price rationing is, then, an explanation for why deposit insurance, which eliminates the non-price rationing, is useful. However, non-price rationing is not inherently inefficient. In the model the non-price rationing arises because of an uninsurable risk and asymmetric information, which together generate a signal-extraction problem for the banks. However, to make the non-price rationing of the

*The views expressed herein are solely those of the author and do not necessarily represent the views of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

bank run inefficient, we find it necessary to include an illiquidity cost of the bank run.

All this is made explicit below. First we describe the model of borrowing and lending alone, without reserves, risky assets, or deposit insurance. Then those attributes are added in order.

2. The model of borrowing and lending

The model is a complicated version of Samuelson's (1958) pure consumption-loans model. There are two types of individuals, one and two. Time is discrete, and everyone lives two periods. There is a continuum of each type of individual born each period indexed by $z \in [0,1]$. The number of type one individuals is $N(z)=N$ for all $z \in [0,1]$ and of type two individuals is $n(z)=n$ for all $z \in [0,1]$, where N and n are positive real numbers with $N > n$. The identical individuals of type one of any particular generation are endowed in the aggregate with $NK>0$ units of the single non-storable but transferable consumption good in their first period of life but are endowed with nothing in their second period of life. The identical type two individuals of any particular generation are endowed with nothing in their first period of life but are endowed in the aggregate with $nK>0$ units of consumption goods in their second period of life. This setup is introduced in Wallace (1980).

There exists a quantity of M dollars of fiat money which the young of type one get in exchange for goods. In addition, there exists a costly intermediation technology, whereby individuals of type one can trade goods today for goods tomorrow with individuals of type two. The process can be viewed as occurring as follows. In exchange for deposits, promises of dollars tomorrow, an intermediary gets dollars from young individuals of type one. These dollars are then lent to young individuals of type two for promises of dollars tomorrow. The young of type two then exchange these dollars for goods. For the sake of simplicity, a very simple and unrealistic intermediation technology is assumed. The intermediation cost is assumed to be proportionate, with constant of proportionality g, to the goods value of the dollars of deposit.

In addition to money, there also exist government bonds (B). A government bond is a default-free promise by the government of a dollar tomorrow. These government bonds cannot be held directly but must be intermediated through the costly intermediation technology. For a defense of this method of generating interest on government debt, see Bryant and Wallace (1979) and (1980). The interest payments on bonds are paid for by a costless system of equal lump-sum taxes on the type one individuals in their youth.

Once again for simplicity, we will only consider stationary monetary equilibria where the value of fiat money is constant through time.

2.1. The individual's problem

The individual maximizes his utility of first- and second-period consumption. Assume a common increasing, strictly concave utility function. Let $c_j^i(z)=c_j^i$ be the consumption in jth period of life of individuals z of type i. The utility of an individual of type i is $u(c_1^i, c_2^i)$. Let M^1 be the money holdings of type one individuals, D be deposits held by type one individuals, M^2 be the borrowings of type two individuals, r be the rate of interest on loans, s be the dollar price of a bond, and P by the goods price of a dollar. We have assumed a stationary equilibrium so these variables are constant through time. Then

$$\begin{aligned} c_1^1 &= K - PM^1 - PD - P(1-s)B/N, \\ c_2^1 &= PM^1 + PD, \\ c_1^2 &= PM^2, \\ c_2^2 &= K - (1+r)PM^2. \end{aligned} \tag{1}$$

Note that we have assumed that the rate of return on deposits is zero. As money is held in the portfolio of type one individuals and deposits are a perfect substitute for money, this is a necessary condition for a monetary equilibrium.

2.2. Intermediaries

We assume free entry into intermediation so that the profits from this activity are zero. Consider the intermediaries set up in time t. Their receipts minus expenditures in time t are $ND-\{gND+nM^2+sB\}$, and in time $t+1$ are $[1+r]nM^2+B-ND$. Setting both terms equal to zero yields $(1+r-1/(1-g))nM^2+(1-s/(1-g))B=0$. It follows that for B, $M^2>0$

$$\frac{1}{1+r} = 1-g = s. \tag{2}$$

Our simple linear intermediation technology yields a unique rate of interest on bonds independent of the amount of bonds outstanding. Similarly, the rate of return on loans is uniquely determined with the borrower paying the intermediation cost.

2.3. Equilibrium conditions

Our first equilibrium condition is that all goods are consumed or used up in intermediation. $Nc_1^1+Nc_2^1+nc_1^2+nc_2^2+gNPD=(n+N)K$. This can be rewritten as

$$P(1-s)B+nrPM^2=gNPD. \tag{3}$$

This expression is nothing but the constraint that receipts minus expenditures of intermediaries sum to zero. Our second equilibrium condition is that all the money held between periods is held by type one individuals, or

$$NM^1=M. \tag{4}$$

The last equilibrium condition is just that bonds be held by intermediaries.

Substituting (2) into (3), we conclude that $D=B/N+(n/N\,(1-g))M^2$. From (1) and (2) it is clear that PM^2 is completely determined by $u(\cdot)$, K, and g. Let $\gamma=P(n/N(1-g))M^2$, $m=M/N$, $b=B/N$. Then the first two expressions of (1) can be rewritten as

$$c_1^1=K-Pm-P(1+g)b-\gamma, \quad c_2^2=Pm+Pb+\gamma. \tag{5}$$

Let us compare alternative stationary equilibria with different proportions of money and bonds, but holding $m+b$ constant. These comparisons can be viewed as analyzing open market operations, as discussed in Bryant and Wallace (1980). It is clear that increases in b only increase the lump-sum costs to individuals of type one in their first period of life. If both current and future consumption are strictly non-inferior, it follows that open market sales are inflationary as in Bryant and Wallace (1980).

3. Reserves

Now we turn to some simple modifications of the model that generate reserve holdings of intermediaries. To do this, we introduce a demand for liquidity and a constraint that bonds and loans be illiquid.

Assume that type one individuals get their endowment at the beginning of their first period of life, but type two individuals get their endowment at the end of their second period of life. Government bonds also pay off at the end of the period. All individuals are indifferent to consuming at the beginning or the end of the period. However α percent of the type one individuals die in the middle of their second period of life. For each individual there is an independent drawing on whether he will die early. These individuals find out that they are going to die early some time after the first-period markets close. However, there is no way that the individual can demonstrate that he will die early, so it is not an insurable risk. The individual who discovers he will die early has no use for his claims to end of second-period consumption in the form of intermediary deposits. He needs to trade, directly or indirectly, with the young of type one next-period. The reader should note that we are not seriously advancing premonition of death as an explanation for an uninsurable demand for liquidity. Rather, this is just a device for introducing such a demand to the model.

Now we introduce the illiquidity cost that generates reserves. Let us suppose that trading claims to next-period output on short notice is prohibitively costly, costly at a rate greater than g. Therefore, a direct trade of claims by 'early diers' to the other type one individuals of the same generation for money, or to the next generation of type one individuals for goods, causes a substantial loss to the 'early diers'. Indeed, the loss is in excess of the cost to the intermediary of storing fiat money. However, the early withdrawal of money is costless, or at least much less costly.

Any intermediary of positive mass is perfectly diversified against this risk of 'early diers', exactly α percent of its deposits will be held by people who die young. Therefore, the intermediary can hold α percent of its deposits as fiat money and, with certainty, just meet the demands of the 'early diers'. Moreover, while the 'early diers' are impossible to identify, only they will have motive to withdraw early. Therefore, all the intermediary need do to provide 'insurance' for this uninsurable event is allow deposits to be withdrawn at any time. By providing this service, the intermediary reduces the risks faced by individuals, and therefore, it does so.

Notice that intermediary liabilities taking the form of demand deposits depends only upon the uninsurable risk, the demand for liquidity. The illiquidity of bonds and loans is introduced to generate currency reserves.

4. Bank runs and deposit insurance

While the uninsurable risk introduced in the previous paragraph generates demand liabilities, this is not sufficient to produce bank runs. To generate bank runs, we add risky intermediary assets and asymmetric information. What is crucial for the bank runs is that the coexistence of the uninsurable risk of early death and the asymmetric information on the risky assets give the intermediary a signal-extraction problem.

Let us now assume that the endowment of type two individuals is risky. There is a small probability that all type two individuals of a particular generation will be endowed with less than nK units of the consumption good. Because this loss occurs to everyone, there is no gain to diversification. Naturally, this riskiness is reflected in the loan rate, which now can exceed $g/(1-g)$, and in the rate on deposits, which now can exceed zero. Moreover, let us assume that some percentage β of type one individuals discover that this bad outcome will occur.[1] This knowledge is randomly distributed over the population, it appears just before individuals discover whether they will die young, and the knowledge cannot be verified. The rest of the population learns of the outcome only when it occurs. The knowledgeable individual reacts to the knowledge of a bad outcome by withdrawing his deposits. This is a bank run. The intermediary cannot distinguish between 'early diers' and knowledgeable individuals. If it could pay for the information on the loans, the intermediary would, but an individual would always tell the intermediary that the loans are bad in the hope they turn out to be so.

What does the intermediary do in a bank run? Of course, once more than α percent of deposits are withdrawn, the intermediary realizes that a bank run is on, and that its loans are bad. It could simply freeze accounts, but this would be a great hardship on the early diers who would get nothing for their deposits (of course, the rate paid on deposits would compensate them, type two individuals actually bear the cost). It could suspend convertibility into currency, as has been done historically, or convert to currency at a much reduced rate if it can trade its assets for currency. This imposes a reduced, but still potentially substantial, cost on the 'early diers'.

What makes the bank run a poor allocation scheme? Suppose, for the moment, that the loans and bonds do not suffer from illiquidity, so that the 'early diers' are not hurt more than the others in a bank run. Is the first come first serve allocation of the bank run still inefficient? By the structure of the problem, α percent of the type one individuals cannot share the risk of type two endowments, which is, in some sense, inefficient. However, as long as banks can suspend full convertibility when α percent of deposits are withdrawn, the asymmetric information and deposit liability does not add to this irreducible cost.

Now let us consider government insurance of deposits. Unless the government can extract the information on the outcome to type two individuals in a way that the private sector cannot, the government cannot get the α percent of type one individuals to share the risk. However, the inefficiency of first come first serve, given the illiquidity of loans and bonds, does raise the possibility of insurance of deposits.

First, let us demonstrate that the private market may not be able to solve the problem. First consider type one individuals. The only payoff to intermediaries that they can make is their holding of money, but M^1 can be an arbitrarily small proportion of the difference between deposits and intermediary currency reserves. If intermediaries could keep a run secret, they could hold $\alpha+\beta$ percent reserves and solve the illiquidity problem, but this could be very costly and also increases risk. To consider insurance of intermediaries by type two individuals, we must consider the repayment

[1]Actually they need only occasionally get information that the bad outcome is more likely than in the average 'year'.

terms of the loans. If the loans require a repayment which is independent of the realized endowment, then deposits are risky only if the borrowers are reduced to zero consumption in their second period of life. In this case they clearly can offer no insurance. Indeed, repayment schemes are likely to require less than liquidation of the borrower in the bad state, as the loan rate can be substantially increased by doing so. In other words, the intermediaries (and therefore the type one individuals) are likely to partially insure the type two individuals (through the repayment contract) against the bad outcome.

What, then, about government insurance? The government has several devices in the model not available to the private sector, which it can use to insure deposits. In the first place, the government can insure the real value of deposits with a promise to tax the next generation of type on individuals in the bad state. This cannot be done by the private sector because type two individuals cannot share risk with type one individuals of the next generation. Costs of such short-term contracts have been assumed prohibitive. Moreover, even if it could, the market would not generate type two individuals and type one individuals of the next generation bearing the full risk, as this is not optimal. This raises the point that the government's reliance on this tax scheme alone is not optimal.

The government has several other devices that enable it to meet the demands of a bank run. The government can simply print money to meet any deposit demand. If bank runs do not become known to the public, they will still occur under this scheme. This allocation does have the disadvantage of increasing risk as $\alpha+\beta$ percent of the type one individuals get a small loss in deposit value, as most of the resulting price rise will occur only after the bad outcome is realized. If any bank run does become known to the public, then there is no Nash equilibrium. If the informed start a bank run, the dollars they get will be of fully reduced value, so there is no return to making withdrawals. If they do not start a bank run, then the deviant informed person would be able to withdraw his money at full value. However, as in the first case the deviant suffers no gain or loss, but in the second he receives a gain, a bank run seems the most likely outcome. In any case, the 'early diers' will not suffer losses due to illiquidity in this deposit insurance scheme.

The value of such government insurance rests on the supposition that it is cheaper for the government, upon occasion, to print money than for intermediaries to costfully store money every period. Another insurance method that the government can follow is to redeem bonds early when a run occurs. This will allow the intermediary to meet the demands of the run if the run does not become generally known and enough bonds are outstanding. This may require that $M^1=0$ so that the only individuals holding money are 'early diers'. It also will not allow the government to pay off on deposits when the bad outcome is realized, just to meet the run. Note, however, that the interest on government bonds reflects the real cost to the intermediary of holding them. The issuance of bonds amounts to the requirement that the intermediary hold additional reserves, with the taxpayer (type one individuals) bearing the cost rather than type two individuals.

Suppose the repayment terms to loans of intermediaries cannot be made state dependent because, for example, of contract writing or verification costs. Then there are several measures that the government can make to ensure that loans are repaid, and thereby avoid default on loans and, therefore, on deposits. Suppose loans are nominally denominated (as they are). Then any inflationary policy will aid the borrower in making his payment. The government could, for example, initiate or announce a policy of 'helicopter' disbursements of money or use open market sales to drive up the price level when the bad outcome is realized. The government can also buy the intermediary assets at face value, which amounts to printing money to meet deposits as discussed above. This it has done historically. Naturally, all these actions induce complex redistributions of risk.[2]

One thing is clear concerning the government insurance of deposits. Unless the government wants to be continually subsidizing the intermediaries, the government must impose a reserve requirement at α percent of deposits.

5. The stock market

The role of the intermediary is to make a market, so it is not surprising that a model of intermediaries should have implications for the stock market. One problem that analysis of the stock market has met involves asymmetric information sets. Suppose prices reflect the best information held by market participants. Then there is no trading by the informed individuals as they have no gains to make by trading. But then the market does not reflect their information, and there are gains to be made by trading. But the gains disappear only if the prices reflect the best information. Our model provides an answer to this dilemma. Let us suppose that there is an autonomous demand for liquidity, for selling stocks. Then the informed individuals can be the first to sell to these demanders of liquidity or can offer to buy before they do without generating price changes. This gives informed individuals a positive return on their information. In our simple model there is a determinate demand for liquidity, and only one possible outcome once it is exceeded. Presumably, in the stock market the inference problem is much more difficult as there is a stochastic demand for liquidity and innumerable possible states of the world.

[2]As the model stands, the government need not engage in any such activities. To avoid the liquidity costs induced by bank runs, the government could insure deposits only for a period and a half. This does not, however, seem a useful interpretation of the model. In practice, the government cannot distinguish between any of the people who make withdrawals.

Why, then, is there not something analogous to reserves and deposit insurance for the stock market? One answer is that there are — they are called banks. Banks are restricted in their assets because they are explicitly or implicitly insured, and the government wants to restrict the portfolios it insures. Moreover, individuals' demands for liquidity are not for the full value of their assets as in this model, but only for a part of it. Therefore, that individuals pool risk only on a portion of their portfolio does not matter. Another answer is that stocks are for some reason liquid enough already. The only cost of our model that applies is the added risk from asymmetric information, and that is limited by making trades on inside information (which is not randomly distributed) illegal. Moreover, we do observe the government insuring various assets, usually with the express purpose of making them more 'liquid'.

6. Concluding comments

There are several properties of deposit insurance in this model which are worth stressing. In the first place, the deposit insurance does not necessarily keep a bank run from occurring. Secondly, the deposit insurance may cause rather complex redistributions of risk. The reaction of the private sector to the deposit insurance influences and may partially offset the redistributive effects of the insurance. In this model, it is nontheless possible for deposit insurance to redistribute risk in a way which is not open to the private economy. However, the case for deposit insurance seems to rest mostly on the costs of illiquidity and the signal-extraction problem of the banks. Exactly what the effects of deposit insurance are depends upon how the government will meet its insurer's obligation — something which has never been spelled out clearly. If the government insurance is backed by the printing press, deposit insurance may be justified if it is cheaper for the government to occasionally print money than for intermediaries to continuously store it as reserves. Lastly, in this model, the function of bonds in the portfolio of banks is to have lenders take over the burden of reserves from borrowers. Open market operations consist of turning the 'bond reserve' into actual reserve or the reverse as needed, that is, providing an 'elastic currency' as the Federal Reserve was mandated to do.

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