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Abstract

In a model where sunspot panics and information-based bank runs co-exist, we study the importance of the suspension of deposit convertibility rule. Respecting the sequential service constraint and taking salvage value of long-term illiquid investments into account, we show that such a policy, although eliminating the random withdrawal risk that causes sunspot panics, can also make the banking system more vulnerable to bad information about the bank's portfolio investments. This arises due to the one-way bet nature of suspension of convertibility.

Keywords: Bank Runs, Panics, Deposit Contracts, Suspension of Convertibility

JEL Classification: G2

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1. Introduction

Diamond and Dybvig (1983), following Bryant (1980), made an important contribution to the theory of banking, by creating a microeconomic model that captures two functions of the banking sector. By specifically addressing the issues of maturity matching between assets and liabilities, and the provision of insurance to depositors against liquidity risks, they show that bank deposit contracts can be optimal and yet lead to banking panics.

Banks are maturity transformers that take liquid deposits and invest part of the proceeds in illiquid assets. In doing so they pool risk and enhance welfare, but also create the possibility of self-fulfilling bank runs, a second equilibrium of the game which is inefficient. Under the 'bad' equilibrium, short-term creditors suddenly withdraw their loans from a solvent borrower.[1] This occurs because it becomes rational for each consumer to pull his money out, if he expects that the other investors will behave in the same way. Because of the illiquidity of the investment, the bank cannot honor all its liabilities if all agents present them for redemption, and given the existence of a sequential service constraint, if a panic was to take place the agents at the end of the line would suffer losses, receiving less than promised.[2] In order to avoid incurring such losses, they will choose to step to the head of the line, causing the very event they imagined. If everyone decides to run we get a self-fulfilling panic.

The main question regarding the model of Diamond and Dybvig arises in relation to the causes of panics. They suggest it may be because of "a random earnings report, a commonly observed run at some other bank, a negative government forecast, or even sunspots" (p. 410), hence the term 'sunspot' panics.

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[1] In Diamond and Dybvig banks are vulnerable to runs because of the existence of multiple equilibria. Postlewaite and Vives (1987) show in an example based on the Prisoner's Dilemma situation that a bank run can also exist as a unique equilibrium with positive probability. This equilibrium has the feature that it does not have to be conditioned on an exogenous event, such as sunspots.

[2] No justification for the existence of the sequential service constraint was originally given in the model of Diamond and Dybvig, until Wallace (1988) suggested the spatial separation of agents. Calomiris and Kahn (1991) also noted that the first-come first-served rule warrants explanation, after comparing this property with the analogous situation of bankrupt firms, but recognised it as a rule and explained it as compensation for those who choose to invest in information and as a tool that eliminates the resulting free-rider problem.

An alternative view on the cause of bank runs offers a more clear rationale for their existence. Following Diamond and Dybvig, this view tries to model runs triggered by fundamentals, in contrast to pure panics as suggested by the sunspot theory. In Jacklin and Bhattacharya (1988), the long-term investment is risky, in the sense that it offers a variable return. Runs are caused by rational revisions in beliefs about the riskiness of the bank's portfolio performance.[3] While in Diamond and Dybvig bank runs occur because depositors collectively choose a Pareto-dominated equilibrium, in Jacklin and Bhattacharya interim information about the bank's investment in the risky long-lived assets causes depositors to prefer early withdrawal, a demand that the bank cannot support with its assets, leading to 'information-based' bank runs.[4]

Our paper is based on a hybrid model combining the environment of Diamond and Dybvig and of Jacklin and Bhatacharya, in order to study the importance of suspension of convertibility in information-based runs. Diamond and Dybvig identified the suspension of convertibility as a mechanism that can eliminate the Pareto-inferior equilibrium of the bank's standard demand deposit contract.[5] Jacklin and Bhatacharya, by allowing withdrawals only up to specific proportions also make this assumption indirectly.[6]

Suspension of convertibility is central to the issue of bank runs and panics. As Calomiris and Gorton (1991) point out "The term banking panic is often used somewhat ambiguously and, in many cases, synonymously with events in which a bank fails…" (p. 112), while their preferred definition is: "A banking panic occurs when bank debt holders at all or many banks in the

[3] Alonso (1996) makes the banks fully rational, in the sense of allowing them to design their contracts with the knowledge that bank runs can take place. In this environment, banks can design run-preventing deposit contracts. However these may not be profit-maximising, and the banks may choose contracts with the property that runs will occur with positive probability.
[4] Chari and Jagannathan (1988) emphasise the panic aspect of this type of runs. A portion of the depositors, uninformed about the true values of their bank's assets, can only learn about the state of the bank by observing its line for withdrawals. However they cannot distinguish whether there is a long line because of consumption needs or because informed depositors are getting out early. They may then infer (correctly or not) that the bank is about to fail and withdraw.
[5] This assumes that aggregate consumption demand is certain. If withdrawals are stochastic however, a bank-run will be averted but optimal risk sharing will not be achieved.
[6] In Chari and Jagannathan suspension of convertibility is central to the existence of their bank and in yielding superior allocations to the market equilibrium in terms of ex-ante expected utility, leaving however some individuals worse off than others ex-post.

banking system suddenly demand that banks convert their debt claims into cash (at par) to such an extent that the banks suspend convertibility of their debt into cash…" (p. 112).

There have been two studies that concentrated on suspension of convertibility. Engineer (1989) shows that in a four-period version of the Diamond and Dybvig model, the policy of suspending deposit convertibility is not as effective and may not eliminate the bank run equilibrium, which can occur even if the bank can adjust new withdrawal payments after observing too many withdrawals. Gorton (1985) in an environment of incomplete information about the bank's investments, portrays a bank's suspension of convertibility as a signal to depositors that continuation of the long-term investments is mutually beneficial.

The model presented here makes use of the interim information structure and the contract offered by the bank on the variable-return, long-term investment of Jacklin and Bhatacharya, while following Diamond and Dybvig in using corner preferences for the consumers, as they either care about early or late consumption.[7] To this framework we add Cooper and Ross's (1991) extension with respect to the early liquidation of the illiquid investment.[8] We find that the existence of suspension of convertibility as a policy alters the critical point of bad news needed for an information-based run to be triggered. What is interesting is that it does so adversely, by making the economy more prone to an information-based run.[9]

When suspension of convertibility is not available the late consumers who decide to run will have to forego their initially assigned allocation, unlike the late consumers under suspension of convertibility, who will be able to receive their assigned allocation if they don't succeed in getting something

[7] Allen and Gale (1998) present a model with similar characteristics, which was developed in order to study optimal (policy for) financial crises. They adapt the information-based view of bank runs in a simple set-up, however discard the assumption of first-come first-served, and at the same time study the consequences of liquidation costs indirectly, by assuming that the return to storage by early withdrawing late consumers is lower than the return obtained by the bank. In our model, we respect the sequential service constraint, and study the consequences of liquidation costs directly, by considering the salvage value of long-term illiquid investments.

[8] Diamond and Dybvig consider the role of liquidity in their model, but their liquid investment technology (storage) is completely dominated by the illiquid one. This is because they assume that early liquidation of the long-term productive technology results to a payoff equal to the initial investment in the technology, thus matching the service that storage provides. Cooper and Ross demonstrate this and modify the model to study the importance of salvage value more carefully.

under the run-period.[10] This can be seen as the cost incurred in participating in a casino game (all or nothing respectively). When the game is offered to the to-be-participants (i.e. when it would be profitable to run), they have to consider both the cost of taking part and also the probability of winning. Under suspension of convertibility the withdrawers will have nothing to lose and they will take up the game no matter the probability. On the other hand if the policy is one without suspension of convertibility, both the cost and the probability of winning will play a role in making a decision to participate (and they may want the game to be more profitable in order to take part [11]). Thus suspension of convertibility offers a one-way bet to consumers (given that it is profitable to participate), as for them to play is to win.

We begin in Section 2 by presenting the environment of our model and by providing a general framework for the workings of a banking system in such an economy. Next, in Section 3, we characterize the bank's contract more specifically, and solve for the optimal allocations, while in Section 4 we consider the possibility of bank runs, both sunspot and information-based ones. We analyze the consequences of the bank's suspension of convertibility for information-based runs in Section 5, and consider the importance of leftovers with the bank in the case of a run under such a rule in Section 6. This is followed by concluding remarks in Section 7.

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[9] But at the same time eliminating the possibility of a sunspot run.
[10] This is so, because under a policy of suspension of convertibility early liquidation of the long-term investment is not allowed, unlike the case without the policy in place.
[11] Profitability in this sense is associated with the difference between the expected returns from withdrawing early or late.

2. General Framework

Like Diamond and Dybvig our model has three periods (T=0, 1, 2) and a continuum of agents whose measure is normalized to one, each endowed with one unit of good at T=0. These agents are ex-ante identical, and each faces a privately observed, uninsurable risk of being impatient (cares only about consumption in T=1) or patient (cares only about consumption in T=2). The liquidity shock is independently and identically distributed: with probability p they are early consumers, with $(1-p)$ late. Their types are revealed to them in period T=1.

Consumption goods can be stored from one period to the next at no cost. Alternatively, and similarly to Jacklin and Bhattacharya, there is a long-lived productive technology, whose return is a random variable $\tilde{R}$, about which there is interim information at T=1. At T=0, with probability q the return in T=2 is low R_l, and with probability $(1-q)$ it is high R_h.

In contrast to Jacklin and Bhattacharya and in accordance with Cooper and Ross, we attempt to capture the irreversibility of this investment by assuming that early liquidation of this long-term technology in T=1 yields only $(1-t)$, where $t \in [0,1]$. Diamond and Dybvig assumed $t = 0$, thus ignoring early liquidation costs, while Jacklin and Bhattacharya at the other extreme assumed $t = 1$, a zero return and thus complete irreversibility.

Following Diamond and Dybvig, banks will design optimal insurance contracts to resolve the problem of the liquidity shock. We assume a sequential service constraint, thus making contracts with consumption payments contingent on the total number of agents in line inconsistent. Without the first-come first-served assumption, panics would not take place and the model would not reflect the history of banking. The omission of the constraint would also lead to the establishment of an efficient early credit market, inconsistent with voluntary participation in an illiquid banking arrangement.[12] To justify the constraint, we follow Wallace (1988) in

[12] Banking can be seen as a substitute for market activity in a world where agents are isolated. Without isolation, the outcome obtained by the intermediary can also be obtained by the credit market and therefore there would be no reason to assume that banks would arise. See Jacklin (1987).

assuming spatial separation of agents. If consumers are assumed to be isolated, then they will be prevented from co-ordinating their withdrawal.[13]

We consider two policy-states, under which suspension of convertibility may or may not be in place.

Consider program P, which solves for the first best:

$$\underset{c,I}{Max}\, U = \mathrm{p}u(c_1) + \mathrm{r}\,(1-\mathrm{p})[\mathrm{q}u(c_{2l}) + (1-\mathrm{q})u(c_{2h})] \tag{1}$$

subject to:

$$\begin{aligned} &\mathrm{p}c_1 = 1 - I \\ &(1-\mathrm{p})c_{2l} = IR_l \\ &(1-\mathrm{p})c_{2h} = IR_h \end{aligned} \tag{2}$$

where $\mathrm{r} < 1$ is the discount factor, I is the amount invested in the risky illiquid technology, c_1 is the consumption promised to early consumers and c_{2l}, c_{2h} the consumption allocated to late consumers in the state of the economy where the low, or respectively the high return of the long-term investment is realized.

P provides the solution for the case when the consumer's type is publicly observable in T=1. Alternatively, the consumer's type may not be observable, but under the specific values of the exogenous variables a patient consumer would have no incentive to prefer the impatiens's consumption allocation. That is when the following expressions are satisfied:

$$\left.\begin{aligned} u(c_{2l}) \geq \mathrm{f}\, u(c_1) \\ u(c_{2h}) \geq \mathrm{f}\, u(c_1) \end{aligned}\right\} \text{without Suspension of Convertibility} \tag{3}$$

[13] As a historical phenomenon this was interpreted by Bhatacharya and Gale (1987) as a large number of geographically separated banks in the US due to prohibitions of interstate banking. Wallace's suggestion about the spatial separation can then be used to explain the shock needed to cause sunspot panics. As Chari (1989) points out the source for such variations in the demand for currency can be the agricultural community in the countryside. The nature of the banking system in the US with reserve pyramiding would then cause country banks to behave as individual depositors withdrawing their reserves from city banks.

or alternatively

$$\left.\begin{array}{l} u(c_{2l}) \geq \phi' u(c_1) + (1-\phi')u(c_{2l}) \\ u(c_{2h}) \geq \phi' u(c_1) + (1-\phi')u(c_{2h}) \end{array}\right\} \text{with Suspension of Convertibility} \qquad (4)$$

where by ϕ, ϕ' we denote the probability of being among the people receiving payments when a run on the bank takes place, for the policy-state respectively without and with suspension of convertibility.

Note that when there is no suspension of convertibility and a run takes place, the bank will liquidate all of its investments in the long-term technology and thus the unlucky consumers that do not get c_1 in T=1 will receive nothing afterwards. On the other hand, when suspension of convertibility is in place the bank will not be undertaking any liquidation and the bank's budget will allow payments of c_1 for a mass π of people in T=1, and will then be giving out c_2 in T=2.[14]

If these expressions are not satisfied, they will have to be included as incentive compatibility constraints.[15]

It is also important to make sure that the technology considered is desirable for investment by the consumers. The design of the contract must not force the technology on the investors, as this would lead to an immediate run for any adverse information. So we must ensure that:

$$\theta u(R_l) + (1-\theta)u(R_h) > u(1) \qquad (5)$$

The expected utility from investing in the risky technology must be greater than that obtained from storage.

[14] If late consumers have received c_1 in T=1 then they cannot claim in T=2. This means that the bank is left with unclaimed good in T=2, which will have to be distributed to type 2 withdrawers, thus increasing their consumption allocation in T=2. For the time being assume that only c_2 is paid out in T=2. We deal with this problem later in the paper, and show that it does not affect our results.

[15] This will not be necessary as we show in Appendix 2, following some further assumptions concerning the efficiency of the technology in Section 3.

We can now have a closer look at the probability of being served if a run takes place. Initially assume no suspension of convertibility and consider the probability ϕ. Let N be the number of people that receive c_1. Then:

$$Nc_1 = (1-I) + I(1-\tau) \Leftrightarrow N = \frac{1-I\tau}{c_1} \tag{6}$$

The amount given out to the T=1 withdrawers must equal what will be left in storage plus what will be invested and liquidated at the lower value $(1-\tau)$ in T=1. Then ϕ must be the number of people served over the population total (which is one):

$$\phi = \frac{N}{1} = \frac{1-I\tau}{c_1} = \frac{(1-I\tau)\pi}{(1-I)} \tag{7}$$

Note that a sunspot run equilibrium exists iff $\phi < 1$. Otherwise there is no point for patient consumers to run, since they can receive a minimum of c_1 in T=2 anyway. Furthermore if $\tau < 1$ then ϕ will be an increasing function of I.

Let us now turn to the case where suspension of convertibility is in place. The number of people that receive c_1 is:

$$N'c_1 = (1-I) \Leftrightarrow N' = \frac{(1-I)}{c_1} = \pi \tag{8}$$

thus making $\phi' = N' = \pi$.

Note the importance of suspension of convertibility in this model. First of all, without it both sunspot and information-based runs are possible, and its existence, as in Diamond and Dybvig, eliminates the sunspot runs but does not affect information-based runs, as in Jacklin and Bhattacharya. However there is a further important effect of introducing suspension of convertibility to be considered, one that is studied in the following sections.

3. The Contract

In the above equations define $u(c)=\frac{c^{1-\gamma}}{1-\gamma}$, $0<\gamma\leq 2$.[16] This utility function represents preferences with a relative risk aversion parameter γ. We do not make the assumption of $\gamma>1$ as Diamond and Dybvig do, or $\gamma<1$ as in Jacklin and Bhattacharya, but instead consider the full range of values.

Also, following Jacklin and Bhattacharya, we give the following characteristics to the bank's contract: if $\tilde{R}=R_h$ the bank pays a promised return c_2, and if $\tilde{R}=R_l$ it pays ${R_l}/{R_h}$ of this promised return. The modified optimization problem P looks like this:

$$MaxU=\pi\frac{c_1^{1-\gamma}}{1-\gamma}+\rho(1-\pi)A\frac{c_2^{1-\gamma}}{1-\gamma}\text{ , where } A=(1-\theta)+\theta\left(\frac{R_l}{R_h}\right)^{1-\gamma} \qquad (9)$$

subject to:

$$\begin{matrix}\pi c_1=1-I \\ (1-\pi)c_2=R_hI\end{matrix}\Rightarrow \pi c_1+\frac{(1-\pi)c_2}{R_h}-1=0 \qquad (10)$$

which is the budget constraint of this program.

We will now introduce an important assumption about the exogenous variables in this model. We assume $A(\rho R_h)^{1-\gamma}>1$ for $\gamma<1$, and $A(\rho R_h)^{1-\gamma}<1$ for $\gamma>1$. This implies that we do not need to consider the Incentive Compatibility Constraints, with the implication that we get the same contract under both policy schemes. Even more importantly it ensures that we are not forcing the risk-averse consumers to accept a contract built on a technology that they would otherwise choose not to invest in. These claims are considered in Appendix 1 and 2 respectively.

The first order conditions are:

$$
\begin{aligned}
&\pi c_1^{-\gamma} - \lambda\pi = 0 \\
&\rho(1-\pi)Ac_2^{-\gamma} - \lambda\frac{(1-\pi)}{R_h} = 0 \Rightarrow \rho A R_h c_2^{-\gamma} = c_1^{-\gamma} \\
&\pi c_1 + \frac{(1-\pi)c_2}{R_h} - 1 = 0
\end{aligned}
\tag{11}
$$

where λ is the Lagrange multiplier associated with the budget constraint.

Solving we get:

$$
\begin{aligned}
&c_1 = \frac{1}{\pi + (1-\pi)\dfrac{(\rho A R_h)^{1/\gamma}}{R_h}} \\
&c_2 = (\rho A R_h)^{1/\gamma} c_1
\end{aligned}
\tag{12}
$$

4. Bank Runs

Suppose that suspension of convertibility is not available. As in Diamond and Dybvig, sunspot runs exist under such a contract. Suppose the patient consumer anticipates that all other patient consumers want to withdraw at T=1. The bank is forced into liquidation of the long-term investment. Its available assets will not match demand and the bank fails and shuts down. Note that if demand was matched, a run would not be sensible, and we would have $\phi = N = 1$. So consumer's expectations are self-fulfilling, and an inefficient sunspot run is possible.

In this model sunspot runs coexist with information-based runs under a system without suspension of convertibility. At T=1 agents receive information and update their probability assessment for $\tilde{R} = R_l$ from θ to θ^N. This revised probability may make patient consumers to prefer the payment intended for impatient consumers. Define:

$$
\hat{A}_{NSoC} = (1-\hat{\theta}_{NSoC}) + \hat{\theta}_{NSoC}\left(\frac{R_l}{R_h}\right)^{1-\gamma} \tag{13}
$$

---

[16] It is necessary to impose the condition $\gamma \neq 0$ to ensure that c_1 in (12) is determined.

We want to find out the critical value $\hat{\theta}_{NSoC}$ above which patient consumers will choose to misrepresent their type. This will happen when:

$$\hat{A}_{NSoC}\,\frac{c_2^{\,1-\gamma}}{1-\gamma} < \varphi\,\frac{c_1^{\,1-\gamma}}{1-\gamma} \tag{14}$$

implying:

$$\hat{\theta}_{NSoC} > \frac{(\frac{c_1}{c_2})^{1-\gamma}\varphi - 1}{(\frac{R_l}{R_h})^{1-\gamma} - 1} = \frac{\dfrac{\varphi}{(\rho A R_h)^{1-\gamma/\gamma}} - 1}{(\frac{R_l}{R_h})^{1-\gamma} - 1} \tag{15}$$

Now let's turn to the case where suspension of convertibility is in place. Clearly, as illustrated by Diamond and Dybvig, sunspot runs are no longer possible. However the possibility of an information-based run still exists.

To find out the critical value $\hat{\theta}_{SoC}$ above which patient consumers will choose to misrepresent their type, consider the expression:

$$\hat{A}_{SoC}\,\frac{c_2^{\,1-\gamma}}{1-\gamma} < \pi\,\frac{c_1^{\,1-\gamma}}{1-\gamma} + (1-\pi)\hat{A}_{SoC}\,\frac{c_2^{\,1-\gamma}}{1-\gamma} \Leftrightarrow \hat{A}_{SoC}\,\frac{c_2^{\,1-\gamma}}{1-\gamma} < \frac{c_1^{\,1-\gamma}}{1-\gamma} \tag{16}$$

where $\hat{A}_{SoC} = (1-\hat{\theta}_{SoC}) + \hat{\theta}_{SoC}(\frac{R_l}{R_h})^{1-\gamma}$, implying:

$$\hat{\theta}_{SoC} > \frac{(\frac{c_1}{c_2})^{1-\gamma} - 1}{(\frac{R_l}{R_h})^{1-\gamma} - 1} = \frac{\dfrac{1}{(\rho A R_h)^{1-\gamma/\gamma}} - 1}{(\frac{R_l}{R_h})^{1-\gamma} - 1} \tag{17}$$

The proof that both these critical values are above θ is given in Appendix 3.

5. Consequences of the Bank s Suspension of Convertibility

Consider the two critical values for $\hat{\theta}$ with and without suspension of convertibility:

$$\hat{\theta}_{NSoC} = \frac{\dfrac{\phi}{(\rho AR_h)^{\frac{1-\gamma}{\gamma}}} - 1}{(\dfrac{R_l}{R_h})^{1-\gamma} - 1} \quad \text{and} \quad \hat{\theta}_{SoC} = \frac{\dfrac{1}{(\rho AR_h)^{\frac{1-\gamma}{\gamma}}} - 1}{(\dfrac{R_l}{R_h})^{1-\gamma} - 1} \tag{18}$$

where ϕ is the probability of being among the people that receive c_1 if a run takes place, and has to be $0 \le \phi \le 1$. Then unless $\phi = 1$ and $\hat{\theta}_{NSoC} = \hat{\theta}_{SoC}$, we will have $\hat{\theta}_{NSoC} > \hat{\theta}_{SoC}$ when $\phi < 1$. This means that if we have a policy of no suspension of convertibility, the critical value $\hat{\theta}$ of bad information that needs to reach the market for a run to take place in comparison to a situation with such a policy is higher. This implies that if suspension of convertibility is in place an information-based run may take place more easily than if no such policy was in place.

Let's examine why this is so. Without suspension of convertibility full liquidation takes place, while with the policy in place there is no liquidation. Thus with suspension of convertibility less of the good is available in T=1 for distribution, making the chances of being among those who receive it in case of a run less than without the policy. For this reason we would expect the opposite result to occur, i.e. $\hat{\theta}_{NSoC} < \hat{\theta}_{SoC}$.

However this is not the case, as we also have to consider the cost of not getting anything if the consumer decides to run. We can think of this as a game in a casino, where there is an up-front cost of entering. Without suspension of convertibility this cost is c_2, but with the policy in place it is zero. The game is offered to the agents when $\hat{A}U(c_2) < U(c_1)$, when it becomes profitable to play/run, but the players will have to also consider the cost ($(1-\hat{\theta}+\hat{\theta}\frac{R_l}{R_h})c_2$ or zero) and the probability of winning (ϕ or π) before deciding whether it is also sensible to participate or whether they should wait until it is even more profitable to do so (receive even worse information). For the agents under suspension of convertibility this is a one-way bet, since they have nothing to lose. They will not care about the probability of getting c_1 or not, but they will only concentrate on when it will become profitable to run. On the other hand under a policy of no suspension of convertibility both the cost and the probability will be important in determining the exact point when it will be profitable but also sensible to enter the game. With $\phi < 1$, we get $\hat{\theta}_{NSoC} > \hat{\theta}_{SoC}$.

It is important to notice that we do not just compare the two consumption allocations, or the utility derived from them, but we have to consider expected utilities, which include the probabilities of getting the allocations and whether the allocations will exist for distribution in the first place.

6. Sequential Service Constraint and The Bank s T=2 Leftovers

The sequential service constraint requires that the bank must service its customers sequentially, on a first-come, first-served basis. The first to run will receive c_1, while the remaining will have to wait for consumption until T=2. Therefore it is important to examine the incentives of the first to run from the late consumers. What is crucial to them is that the utility they obtain from running and getting c_1 is higher than the expected utility from obtaining their assigned allocation of $(1-\hat{\theta}+\hat{\theta}\frac{R_l}{R_h})c_2$, that is:

$$\hat{A}\frac{c_2^{1-\gamma}}{1-\gamma} < \frac{c_1^{1-\gamma}}{1-\gamma} \tag{19}$$

If this is not satisfied no-one would run first, since it would not be profitable for them to do so. So for a run to take place this expression as well as the conditions examined earlier that include the probabilities and costs associated with the run must be satisfied. For the case without suspension of convertibility the two expressions (16) and (19) are the same, while for the case without suspension of convertibility if $\hat{A}_{NSoC}\frac{c_2^{1-\gamma}}{1-\gamma}<\phi\frac{c_1^{1-\gamma}}{1-\gamma}$ is satisfied, so will condition (19) given $\phi<1$.

Now consider what happens in the case of a run when suspension of convertibility does take place. Some of the late consumers receive c_1, and will not be claiming in period T=2. This means that there will be an excess of the good in the last period that will have to be distributed to the remaining late consumers. Instead of c_2 suppose they receive $c_2^{real}>c_2$. Then the condition previously given by (16), will now become:

$$\hat{A}_{SoC}\frac{c_2^{1-\gamma}}{1-\gamma}<\pi\frac{c_1^{1-\gamma}}{1-\gamma}+(1-\pi)\hat{A}_{SoC}\frac{(c_2^{real})^{1-\gamma}}{1-\gamma} \tag{20}$$

This expression will be satisfied earlier (in terms of an increase in bad information) than the previous expression we had with c_2, since $c_2^{real}>c_2$. But we must also consider the condition that the sequential service constraint commands. Even though our new condition (with c_2^{real}) is satisfied for a smaller increase in the bad information and would call for a run to take place earlier than the condition with c_2, the run would not start unless it is profitable to do so, that is when $\hat{A}\frac{c_2^{1-\gamma}}{1-\gamma}<\frac{c_1^{1-\gamma}}{1-\gamma}$ is satisfied as well. But this is the same expression as the condition given by (16) that includes the probabilities and costs of a run with c_2 instead of c_2^{real}. Therefore a run will start for the same value of $\hat{\theta}_{SoC}$ whether we take into account the leftover goods at T=2 or not.

7. Conclusion

The question on the cause of banking panics and runs is an empirical one and remains largely unanswered.[17] This uncertainty would suggest that policy making has to consider the importance of both sunspot panics and information-based runs and panics. In this model we consider an environment where sunspot panics and information-based runs may co-exist, while we respect the sequential service constraint and we take into account the importance of liquidation costs. We find that the existence of suspension of convertibility as a policy, although it has the effect of eliminating the random withdrawal risk that causes sunspot panics, can also make the banking system more vulnerable to bad information about the banks' portfolio investments.

This is so because of the one-way-bet opportunity that suspension of convertibility presents to depositors, since it ensures that they have nothing to lose from running to the bank earlier if the unsuccessful long-term investments of the bank make this profitable. Since the investment that will produce their allocation is certain not to be liquidated, it pays to try to get the allocation of the early consumers and save it for a period until consumption, if they judge that this will yield them more utility. On the other hand, without suspension of convertibility, full liquidation will take place in case of a run, and late consumers will loose everything if they don't manage to get the allocation assigned to early consumers. Thus they will be more cautious before starting a run and may demand that such a move is more profitable before they take action.

If we accepted that both sunspot and information-based banking crisis were possible, then this paper would suggest that the ex-ante announcement of the policy of suspension of convertibility, which will shape the expectations of the depositors, should receive more thought, since it can have a good or a bad outcome, depending on the type of the crisis. Our conclusions are in contrast with the view that suspension of convertibility will have no

[17] There has not been much testing on the two competing theories of bank panics. However, studies by Gorton (1988) and Calomiris and Gorton, attempting to determine whether the patterns of panics were more consistent with the sunspot or the information based theories, seem to reject the idea that random shocks are the cause of banking panics. Their analysis suggests that panics originated in bad economic news and bank vulnerability to that news.

effect on information-based runs. Not only it will, but it will also be of an adverse nature.

A note must be made about the bank's policy concerning the leftover commodity after a run, when a policy of suspension of convertibility is followed. As late consumers run to the bank because of their preference for the early consumer's allocation, the amount left over for distribution in the last period of our model will increase. This will have the effect of increasing the amount of the consumption good that will remain, and will be allocated to anyone that claims in the last period. As soon as this allocation becomes equal in expected utility terms with the one promised to early withdrawers, the incentive for running is removed and we would expect an ending to the run. Initially we chose to ignore this effect for simplicity, but later we demonstrated that the distribution of the leftover good to late consumers will not alter the critical point of the bad information needed for the run.

The model here provides a framework which can be extended so as to analyze contagious bank runs. Assuming a pre-announced policy of no suspension of convertibility and allowing for information-based bank runs only, we could compare the ex-post utilities of suspending or not, following a run, thus commenting on the appropriate action ex-post. We would expect to find suspension of convertibility taking place for low values of bad information, while for worse information we would expect full liquidation to be allowed. Thus, suspending deposit convertibility in a region where banks share similar portfolio-return characteristics, could lessen the contagious effect of panic, by suggesting a low value of bad information. However, the possible side-effects to the rest of the economy, where bank portfolio-return characteristics are unrelated to the first-hit region, could give rise to a policy dilemma, since agents observing a suspension in one region, will drop the initial assumption imposed by the ex-ante policy of no suspension of convertibility, and will revise downwards the critical value of bad information that could trigger a run. Thus the policy of suspending deposit convertibility in one region, although saving that region from the contagious panic effects, will make the rest of the economy more vulnerable to bad information about their portfolio returns.

Appendix 1

First consider the economy without the suspension of convertibility rule. The expression that needs to be satisfied is:

$$A\frac{c_2^{1-\gamma}}{1-\gamma} \geq \phi\frac{c_1^{1-\gamma}}{1-\gamma}+0, \text{ where } \phi=\frac{(1-\lambda\tau)\pi}{(1-\lambda)} \tag{21}$$

The patient consumer will choose (always from an ex-ante point of view) his allocation over the impatiens's one, if the predicted period T=2 consumption is more than the allocation assigned to impatient consumers multiplied with the probability of getting this. The expression for $\gamma<1$ then implies $A(\rho R_h)^{1-\gamma}>\phi^{\gamma}$, while for $\gamma>1$ it means $A(\rho R_h)^{1-\gamma}<\phi^{\gamma}$.

Now let's turn to the case where suspension of convertibility is in place. The expression that needs to be satisfied for a viable contract is then simply:

$$A\frac{c_2^{1-\gamma}}{1-\gamma} \geq \pi\frac{c_1^{1-\gamma}}{1-\gamma}+(1-\pi)A\frac{c_2^{1-\gamma}}{1-\gamma} \Leftrightarrow A\frac{c_2^{1-\gamma}}{1-\gamma} \geq \frac{c_1^{1-\gamma}}{1-\gamma} \tag{22}$$

For $\gamma<1$ this implies $A(\rho R_h)^{1-\gamma}>1$, while for $\gamma>1$ it means $A(\rho R_h)^{1-\gamma}<1$.

We know that $\phi\leq 1$, thus the expression for the case with suspension of convertibility is stricter and is the one used so that the need for including incentive compatibility constraints does not arise. Notice that this assumption occurs naturally as we show in Appendix 2.

Appendix 2

Let us consider the constraint imposed more carefully. We do this for $\gamma<1$ but the same intuition holds for $\gamma>1$:

$$A(\rho R_h)^{1-\gamma} > 1\text{, where } A = (1-\theta) + \theta(\frac{R_l}{R_h})^{1-\gamma} \tag{23}$$

If we substitute for A:

$$\begin{aligned}&[(1-\theta)+\theta(\frac{R_l}{R_h})^{1-\gamma}](\rho R_h)^{1-\gamma} > 1\\ &[(1-\theta)R_h^{\ 1-\gamma} + \theta R_l^{\ 1-\gamma}]\rho^{\ 1-\gamma} > 1\end{aligned} \tag{24}$$

Now also consider when the available technology will be preferred to storage by the risk-averse investors:

$$[(1-\theta)\frac{R_h^{\ 1-\gamma}}{1-\gamma} + \theta\frac{R_l^{\ 1-\gamma}}{1-\gamma}]\rho > \frac{1^{1-\gamma}}{1-\gamma}\rho \Leftrightarrow [(1-\theta)R_h^{\ 1-\gamma} + \theta R_l^{\ 1-\gamma}] > 1 \tag{25}$$

That is the expected utility derived from investing in the risky technology must be greater from the utility from storage.

If ρ is close to one, raising it to $(1-\gamma)$ will bring it closer to one, and the two expressions will become identical. Thus the assumption made ensures that the technology is not forced on the risk-averse consumers by the design of the contract, but it is seen as productive, efficient and an investment that they would choose to invest in.

Appendix 3

Notice that:

$$\theta = \frac{A-1}{(\frac{R_l}{R_h})^{1-\gamma} - 1} \tag{26}$$

To prove that $\hat{\theta}_{NSoC} > \theta$, substitute for $\hat{\theta}_{NSoC}$ and θ:

$$\frac{\left(\frac{c_1}{c_2}\right)^{1-\gamma}\phi - 1}{\left(\frac{R_l}{R_h}\right)^{1-\gamma} - 1} > \frac{A-1}{\left(\frac{R_l}{R_h}\right)^{1-\gamma} - 1} \tag{27}$$

leading to the necessary and sufficient condition:

$$A\frac{c_2^{\,1-\gamma}}{1-\gamma} \geq \phi\,\frac{c_1^{\,1-\gamma}}{1-\gamma} \tag{28}$$

Similarly, to ensure that $\hat{\theta}_{SoC} > \theta$, the necessary and sufficient condition is:

$$A\frac{c_2^{\,1-\gamma}}{1-\gamma} \geq \frac{c_1^{\,1-\gamma}}{1-\gamma} \tag{29}$$

Both of these are satisfied, since our initial assumption of $A(\rho R_h)^{1-\gamma} > 1$ for $\gamma < 1$, and $A(\rho R_h)^{1-\gamma} < 1$ for $\gamma > 1$ is derived from these conditions. This is shown in Appendix 1.

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