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JEL Classification Numbers: E44, E5, G21.
Keywords: Banking Crises, Sunspots, Fundamentals, Narrow Banking, Suspension of Convertibility.

Resumen

Este artículo desarrolla un modelo de bancos donde crisis de tipo fundamental (que ponen énfasis sobre variables macroeconómicas como las causantes de crisis bancarias), y crisis de tipo sunspots (donde expectativas auto-generadas crean equilibrios donde los agentes entran en pánico y causan una corrida bancaria) coexisten. Una política de 100% de reservas previene ambos tipos de crisis, pero mantener reservas excesivas de liquidez impide inversiones socialmente productivas, y por ende no es óptimo. Al mismo tiempo, los bancos pierden su razón de ser bajo esta política. Una política de suspensión de convertibilidad puede reducir el bienestar social relativo al caso donde crisis bancarias son permitidas, si la probabilidad de corridas sunspot es suficientemente baja.

Sunspot and Fundamental Bank Runs

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Abstract

This paper builds a banking environment where both fundamental runs (that stress macroeconomic variables, such as negative technology shocks, as the cause of bank runs) and sunspot runs (where self-fulfilling expectations generate equilibria where agents panic and run on banks) coexist. A policy of narrow banking will prevent runs, but holding excessively high levels of liquidity will prevent socially productive investment opportunities, and thus will not be optimal. In addition, banks lose their role as intermediaries under this policy. A policy of suspension of convertibility may reduce welfare relative to the case where bank runs are allowed to take place, if the probability of sunspot runs is sufficiently low.

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1 Introduction

A surge of banking crises emerged since the 1980's in developing countries, particularly in Latin America and Asia. The severe consequences to the economies that suffered these crises have been widely documented[1]. There are two leading views for the causes of banking crises. One view is that they are the consequence of poor economic performance. Examples of such literature are Chari and Jagannathan (1988), Jacklin and Bhattacharya (1988), and Allen and Gale (1998). The second view is that bank runs are a result of multiple equilibria, where a panic is the realization of a bad equilibrium caused by self-fulfilling expectations. In this view, banking crises may be the actual cause of economic downturns. Examples of these are the original Diamond and Dybvig (1983), Freeman (1988), Cooper and Ross (1997), Ennis and Keister (2003) and Peck and Shell (2003). While one literature views the banking crisis as a consequence of poor macroeconomic performance, the other views it as the actual cause of economic downturns.

Empirical work has tried to address these seemingly opposing views. Gorton (1988) and Calomiris and Gorton (1991) examine panics during the U.S. National Banking Era (1863-1914). They find that, during that era, panics were linked to business cycles, and thus caused by fundamentals. They further argue that the sunspot explanation of bank runs is inconsistent with evidence for that period. Demirgüç-Kunt and Detragiache (1998), using a binomial logit model, confirm Gorton's findings for a sample of countries for the 1980-94 period. However, in a theoretical paper closely related to this one, Ennis (2003) shows how Gorton's evidence is entirely consistent with, and perhaps better explained by, a well developed sunspot-based model.

Boyd, Gomis, Kwack and Smith (2001) look at banking crises across countries covering the period from 1970 to 1998. Their findings suggest that it is more the exception than the rule that there are any unusual macroeconomic events that cause banking crises. Thus, for Boyd et al, banking crises may often be the outcome of bad realizations of sunspot equilibria. Fontenla (2004), on the other hand, constructs an index that differentiates between the two types of crises, and then uses a multinomial logit model to examine the factors associated with the occurrence of both types of crises.

[1] See Caprio and Klingebiel (2003) for evidence on the costs of crises, and Ennis and Keister (2003) for the effect of crises on growth.

That work finds evidence indicating that the two types of crises are indeed different, and are explained by different variables. It therefore seems that fundamental and sunspot crises may not be mutually exclusive, but each may best represent distinct states of the world.

Argentina may be a country where both sunspot and fundamental bank runs have recently occurred. The first bank run was triggered by the Mexican crisis that started in December 1994. This crisis had no fundamental effect on Argentina, since both countries have almost no trade relationship. Further, Argentina was coming from a four-year expansion, where GDP growth for the 1991-94 period averaged 8.2%. What caused the bank run was a sudden change in confidence, which set off a bank run. In contrast, the 2001-2003 crisis appears to have marked differences relative to the "Tequila effect." Prior to the crisis, Argentina was immersed in a deep recession that lasted four years. Argentina's GDP declined an average of 2.9% per year between 1999 and 2001. As a result, banks were at the verge of collapsing by December 2001. Thus it appears that the latter crisis was caused by fundamentals.

Given this, we construct a model based on Diamond and Dybvig (1983), where both sunspot and fundamental bank runs are possible. If the causes of crises are different, then they may have different policy implications. In order to study this question, we examine two common proposals for enhancing the stability of the banking system: narrow banking and suspension of convertibility. We first consider a benchmark environment where there are no information frictions on behalf of agents. Here, no bank runs will occur in equilibrium. Banks will offer a contract that maximizes agents expected utility contingent both on the realization of investments and agents' actions. Agents in turn will accept such a contingent contract since they are able to verify bank claims.

We then add information frictions to the model. The presence of information asymmetries has often been denoted as an important characteristic of less developed financial systems. Here, depositors are not able to observe the amount of liquid reserves that banks possess, and some agents are not able to observe the realization of bank investments. Because of these frictions, agents now favor a contract that is not contingent on the realization of investments and other agents' actions. As a result, multiple equilibria arise, which include both fundamental and sunspot bank runs. Under bank run equilibria, banks are forced to liquidate long term investments in order to satisfy depositors demand for liquidity. Liquidation reduces output and forces banks to close. In spite of these multiple equilibria, agents *ex ante* still find it optimal to use banks as intermediaries instead of behaving autarkically.

Narrow banking has often been proposed as a policy to eliminate financial crises. It entails requiring banks to back their entire demand deposits by safe liquid assets. This policy indeed rules out bank run equilibria and implies a very safe banking system. Nevertheless, holding excessively high levels of liquidity will prevent socially productive investment opportunities, and thus will not be an optimal policy. This result agrees with the fact that we generally do not observe narrow banking practices, even when such a measure could be easily implemented unilaterally by banks without the need for explicit central bank regulation. A further implication is that banks would lose their reason to exist under this policy, since agents are able to achieve the same outcome without the aid from banks. Wallace (1996) reaches similar results for a Diamond-Dybvig model with no crises. Our findings extend Wallace's results in an environment that allows for both types of crises to occur.

Suspension of convertibility involves banks suspending payments until the next period once liquid assets are depleted. The threat of suspending payments will prevent sunspot runs, and the actual policy will not be implemented. Suspending the right of agents to withdraw their deposits will prevent liquidation of investments, and thus banks will be preserved. However, this policy will not prevent fundamental runs. When this rule is implemented, a fraction of agents will not be able to access their deposits and thus will be left without consumption. Because of this, we find that a policy of suspension of convertibility, while preventing costly liquidation, nonetheless will fall short of the optimal benchmark outcome. Further, suspension of convertibility may reduce welfare relative to the equilibrium with bank runs, if the probability of sunspot runs is low enough. As the probability of sunspot runs increases, suspension of convertibility may improve on the bank run case, but still not attain the optimum result.

Since suspension of convertibility performs differently depending on what kind of run they face, the assessment of economic conditions that cause a financial crisis becomes critical. *Ex post*, if a bank run is caused by sunspots, then suspension of convertibility performs well. In contrast, when a bank run is caused by fundamentals, a policy of suspension of convertibility will not be optimal. These results are important in light of the recent events in Argentina, where if the recent crisis was caused by fundamentals, perhaps suspending convertibility may not have been the best response.

The remainder of the paper proceeds as follows. Section 2 presents the model. Section 3 illustrates the benchmark environment where no runs occur. Section 4 introduces information asymmetries, where bank runs will take place. Section 5 discusses a narrow banking policy, while section 6 examines suspension of convertibility. Section 7 concludes.

2 The Model

2.1 *Environment*

There are three time periods indexed by t, where $t = 0, 1, 2$. There is a large number of agents, who are endowed with 1 unit of the single consumption good in period 0, and none in periods 1 and 2. Agents are ex ante identical, but are uncertain about their preferences over consumption at dates 1 and 2. At the beginning of period 1, agents learn whether they will want to consume in period 1 or 2, with probabilities π and $(1-\pi)$, respectively. Being patient or impatient is private information to each agent, where the probability π is common knowledge. Agents are von Neumann-Morgenstern expected utility maximizers, with $u(c)$ strictly increasing and strictly concave, $\lim_{c \to 0} u'(c) = \infty$, and $u(0) = 0$.

There are two investment technologies: a safe storage technology and a stochastic production technology. The storage technology transforms one unit of consumption in period 0 into one unit of consumption at either periods 1 or 2. The production technology transforms one unit invested in period 0 into R units in period 2, where R is an $i.i.d.$ random variable with distribution function $F(R)$, which is common knowledge. Further, we assume the expected value of R to be greater than the return on storage, $E[R] > 1$, with the lower bound, $\underline{R} < 1$. However, if the production technology is liquidated in period 1, then it will yield a return $r = \underline{R}$. This is to say that liquidating investments will always be costly.

2.2 *Banks and Timing*

Banks arise naturally in this setting to invest optimally on behalf of agents, and to provide insurance against the uncertainty of consumption preferences. We assume that banks are profit maximizers, but operate in a perfectly competitive environment, and thus will offer a contract that maximizes the expected utility of agents, subject to banks telling the truth.

Both agents and banks are assumed to observe at the beginning of period 1 the return to the illiquid investment, R. This update in information may change incentives, where patient agents may want to misreport their type for low realizations of investment returns. Thus, agents may have the incentive to run on banks based on a low realization of output[2]. We denote this scenario as a fundamental bank run.

Also at the at the beginning of period 1, all agents observe the realization of an extrinsic random variable. This random variable is completely unrelated to the fundamentals of the economy, but may influence the economy to the extent that agents believe it does. In this sense, a sunspot variable may trigger a banking panic, where it becomes rational for agents to run on banks, if they expect that the other agents will run also.

The timing of events follows: in period 0, banks announce contracts, agents receive their endowments and deposit them in banks. Banks then choose their portfolio allocation, i.e. the mix of safe and risky investment. At the beginning of period 1, agents learn their preferences about the timing of consumption. Simultaneously, next period's R becomes public, and agents observe a sunspot variable s. Following this, banks pay to agents that report to be impatient. At the beginning of period 2, R is realized and banks dispense payments to patient agents.

3 Full Observation

In this section, we discuss the equilibrium for an economy where agents fully observe both the economy's fundamentals and banks' reserves. That is, in addition to their private idiosyncratic shocks, agents are assumed to have access to the same information as banks. In particular, all agents observe both R and when banks' storage reserves are depleted. Also, banks are not allowed to suspend payments nor borrow funds from a central bank.

3.1 *No Runs*

After agents deposits their endowments, banks use these deposits to invest in storage and the illiquid technology. Let i denote the illiquid investment and h denote storage. Thus, banks will face the constraint

$$h + i = 1. \tag{1}$$

Banks will offer returns c_1 and c_2 to impatient and patient agents, respectively. Let δ denote the fraction of the investment that is liquidated in period one, and α be the fraction of storage that banks carry over to the next period. Then, the bank's resource constraints can be written as:

[2] In a similar manner to Chari and Jagannathan (1988), Jacklin and Bhattacharya (1988), and Allen and Gale (1998).

$$\pi c_1 = (1-\alpha)h + \delta r i \tag{2}$$

$$(1-\pi)\, c_2 = \alpha h + (1-\delta) R i \tag{3}$$

When agents do not run on banks, banks find it optimal to set $\delta = 0$, since the return on liquidating investments dominates the return on holding storage. The optimal fraction of storage banks hold across periods, α, will be equal to zero in this case, since the return on storage holdings is dominated by the expected return on holding investments. Thus, storage reserves will optimally be exhausted and no costly liquidation will occur when there are no runs.

Lemma 1: When agents do not run on banks, banks will offer a contract given by the deposit returns

$$c_1 = \frac{h}{\pi} \tag{4}$$

$$c_2 = \frac{R(1-h)}{(1-\pi)} \tag{5}$$

The proof follows closely the discussion above and is therefore omitted. Equations (4)and (5) depict the standard deposit contract assumed in the Diamond-Dybvig literature, where now the return to patient agents is a random variable, unknown at the time banks choose their portfolio allocations.

3.2 *Low Output*

The randomness of the return to patient agents implies that the relation of the returns to patient versus impatient agents will depend on the random variable R. In particular, we can write the output threshold for which $c_1 = c_2$ as

$$R^* = \frac{(1-\pi)}{\pi} \frac{h}{(1-h)} \tag{6}$$

For realizations of $R>R^*$, the return for patient agents will be greater than the return for impatient agents, and the bank problem may be as discussed above. However, for realizations of $R<R^*$, we have $c_1 > c_2$. Recall that both agents and banks observe the prospective R simultaneously to agents learning π and before they report to banks. Thus, if patient agents learn $R<R^*$, then they will have the incentive to pretend to be impatient. Since banks

also observe R, they are able to correctly predict agent's actions. Thus, banks are capable of offering all agents the same amount of consumption.

Lemma 2: When banks observe $R < R^*$, they will pay

$$c^f = h + R(1 - h) \tag{7}$$

to all agents, and no bank run will occur.

Banks will pay in storage to impatient agents and forward the remaining storage to the next period, where it will pay patient agents a mix of storage and the returns on the production technology. Agents *ex ante* will prefer this risk sharing contract, where consumption is equal for all, for low realizations of output. They will accept a contract contingent on the signal on R, since they are able to observe such a signal. Finally, patient agents will truthfully report their type and no run will occur, since they gain no additional consumption by pretending to be impatient.

3.3 *Sunspots*

Suppose that, at the end of the first period, there is a shift in market sentiment that brings a wave of pessimism. This wave of pessimism is triggered by some extrinsic variable, completely unrelated to the fundamentals of the economy. That is, a sunspot variable, which we can define as s, triggers a run, where consumers panic and withdraw in period one. This panic will be an equilibrium if agents believe that other agents are withdrawing early, and the share of agents who do so is large enough to force complete liquidation of the long term asset. If no assets will be left for late withdrawers, then it is agents' best response to attempt to withdraw early also.

Central to this self-fulfilling equilibrium is the sequential service constraint. That is, banks will honor agents' demand for liquidity on a first-come, first-served basis. This, coupled with costly liquidation, will render banks' liquid assets insufficient to meet liquidity demands from all agents. This implies that agents who end up "late in line" may not be able to receive any payments. Thus, if agents believe enough agents are withdrawing early, they will have the incentive to run on the bank in an effort to be early in line.

However, under the information assumptions of this section, banks will be able to prevent such a sunspot panic. Once they pay the return to the first π share of agents and thus deplete their storage reserves, they can offer to the remaining $(1-\pi)$ agents a return low enough so that no agent late in line will be left without consumption.

Lemma 3: When banks observe a fraction greater than π reporting to be movers, they can offer a deposit return

$$c_1^s = \frac{r}{(1-\pi)}(1-h) \tag{8}$$

to all remaining agents. Then, no sunspot panic will occur.

Under this rule, a sunspot run is not an equilibrium, since a potential payoff of c_1^s ensures that no agent would be left without consumption when all agents chose to run. A patient agent who chooses not to run will get a payment of $c_2 > c_1^s$ if it chooses to wait until next period. This is regardless of what all other agents do, since banks will be able to save an agent's share until the following period[3]. Hence, a threat of paying c_1^s suffices to prevent a sunspot run, where the actual payment does not occur in equilibrium. Notice that agents will *ex ante* accept a contract that specifies this rule, since they are able to verify banks claims of depleted reserves.

3.4 *The Bank's Problem*

Given the previous discussion, the bank's problem has the form

$$V^{fo} \equiv \max \int_r^{R^*} u(c^f)f(R)dR + \int_{R^*} \left[\pi\ u(c_1) + (1-\pi)\ u(c_2)\right] f(R)dR \tag{9}$$

subject to the deposit return schedules (4),(5) and (7), and the endogenous output threshold (6). The first term represents banks recognizing the change in incentives triggered by low output, and thus offering the same consumption to all. The second term represents the standard Diamond-Dyvig case, where $c_2 > c_1$. Notice that c_1^sdoes not appear in the objective function, since the actual payment is not an equilibrium. Agents always report their type truthfully in this problem, and no bank run occurs. The solution to this problem defines the optimal portfolio allocation and consumption schedule.

[3] The agent's share in this case is $\frac{(1-h)}{(1-\pi)}$, where if the agent withdraws early, it will be multiplied by r, whereas if she withdraws late, it will be times R, where $R > r$.

4 Bank Runs

In this section we consider the same environment discussed so far with two exceptions. First, similar to Chari and Jagannathan (1988) and Jacklin and Bhattacharya (1988), we assume that a fraction of agents are not able to observe the return to the illiquid investment, R. In this case we assume that impatient agents will not be able to observe the signal on R, and thus will not be able to verify a contingent contract. Since banks are assumed to operate in a perfectly competitive environment, they will offer contracts that maximize the expected utility of agents. However, once a bank receives deposits from agents, it faces a time-consistency problem. Potentially, if agents accept a contingent contract which they can't verify, banks can claim a lower than the true return. In particular, banks could always deceive uninformed impatient agents by claiming a return $R = r$, and paying them accordingly.

Second, we assume that all agents are not able to observe when banks' storage reserves are depleted, as in Freeman (1988). Here again, banks could claim that their storage reserves are depleted, and pay a lower return than promised if agents accepted a contract they could not verify.

Since agents may not be able to verify claims from banks, they *ex ante* will prefer a contract that is neither contingent on R nor the fraction of withdrawals. Since banks are not able to adjust payments contingent on this information, they will be forced to liquidate the production technology in the event of a bank run, and close down.

4.1 *Low Output Runs*

When patient agents observe a return below R^*, then they will have the incentive to misreport their type. Banks also observe the return on investments, and thus know a run will occur before agents come to the bank. However, impatient agents will not accept a contract contingent on R, since they can't verify it. Further, once banks run out of storage reserves and start liquidating investments, they will not be able to divide the proceeds evenly among the remaining depositors, since agents can't verify claims of depleted reserves. Key to this argument is the sequential service constraint, where agents arrive at the bank at different random times to withdraw, and are served as they arrive. In particular this means that banks are not capable of accumulating withdrawal demands, and then make payments contingent on the total[4]. Given this, banks will pay out the promised return $c_1$to agents until they run out of funds. That is, they will only be able to honor the fraction

$$\psi = \frac{h + r(1-h)}{c_1} \tag{10}$$

Lemma 4: When banks observe $R<R^*$, they will pay c_1 *to a fraction* $\psi \in [\pi, 1)$ *of agents and close down.*

Figure 1 summarizes the expected payoffs to a patient agent. As long as $c_1 > c_2$, the unique Nash equilibrium is the one where all patient agents will run. When the equilibrium payoff is lower than the return where all agents truly report their type, that is, when $\psi c_1 < c_2$ the game will be an example of the prisoner's dilemma.

Figure 1

		All Other Patient Agents: run	no run
Patient Agent	run	ψc_1	c_1
	no run	0	c_2

4.2 *Sunspot Panics*

When $R>R^*$, no runs based on low output will occur. However, suppose that a sunspot variable s triggers a run, where consumers panic and withdraw in period one. Here, banks will not be able to offer c_1^s as in the full observation case, since agents will not accept such a contract. Agents are not able to observe reserves being depleted, and thus could be deceived by banks when there are no sunspot panics. Thus, without being able to verify claims by banks, agents will not accept a contract contingent on the number of withdrawals. As in the run based on low output, banks will pay out the promised return c_1 until they run out of funds.

Lemma 5: When $R>R^*$ a sunspot run may occur. Banks will then offer the deposit return c_1 to a fraction $\psi \in [\pi, 1)$ of agents and close down.

[4] See Wallace (1988) for a complete justification of the sequential service constraint, and its historical importance in bank runs.

Note that the sunspot variable may be observed for $R>R^*$, but in this case a run will occur with certainty, thus overriding the effect s may have on the lower range of R. The payoff matrix is again given by *figure 1*, but now we have $c_2 > c_1$, and two Nash equilibria arise: where all agents run, and where all patient agents choose to wait and withdraw in period 2.

4.3 *The Bank's* Problem

With information frictions, bank runs may occur. Because of this, banks may want to hold "excess liquidity"[5]. That is, they may want to set $c_1 < \frac{h}{\pi}$. Thus, we go back to constraints (2) and (3). It will still be optimal to set $\delta = 0$, so combining (2) and (3) to eliminate α yields

$$(1-\pi)c_2 = h + R(1-h) - \pi c_1 \tag{11}$$

Given this the output threshold R^* for which $c_1 = c_2$ becomes, from (11)

$$R^* = \frac{c_1 - h}{(1-h)} \tag{12}$$

Define ϕ as the probability of a sunspot run occurring when $R>R^*$. Then the bank's problem has the form

$$\begin{aligned} V^{br} \equiv \max_{h,\ c_1} \int_r^{R^*} \psi u(c_1) f(R) dR + \phi \int_{R^*} \psi u(c_1) f(R) dR + \\ (1-\phi) \int_{R^*} \left[\pi\ u(c_1) + (1-\pi)\ u(c_2)\right] f(R) dR \end{aligned} \tag{13}$$

subject to the resource constraint(11), the endogenous output threshold (12), and the also endogenous fraction of agents served in a run, given by (10). The first term of the bank's problem represents the fundamental run due to incentives triggered by a low realization of output. The second term represents the sunspot equilibrium. Finally, the third term represents the equilibrium with no runs.

Banks can still choose a run-proof contract in this environment. Such a contract will have the constraint

$$c_1 \leq h + r(1-h). \tag{14}$$

[5] As in Cooper and Ross (1998). See also Ennis and Keister, forthcoming.

This constraint makes $R^* = r$ in (12), thus ensures $c_1 \leq c_2$ always, the first term in (13) disappears, and no fundamental run will occur. Also, $\psi = 1$ from (10), thus by guaranteeing that there will be enough liquidity in the bank to pay all agents, ϕ becomes equal to zero, and a sunspot run will not be an equilibrium either. Therefore, the bank's problem in (13) includes the possibility of choosing a run-proof contract, depicted by it's third term, where $\phi = 0$.

In spite of ruling out runs, a run-proof contract may be too costly, particularly in situations where the probability of bank runs is small. Thus, when the probability of runs is small enough, agents will prefer a contract that allows for runs.

5 Narrow Banking

Narrow banking has often been proposed as a policy to eliminate financial crises. It requires demand deposits to be backed entirely by safe liquid assets. In our environment this would entail requiring banks to exclusively hold storage, which is both liquid and non-stochastic, to meet the withdrawing needs of agents. In our case it involves setting $h = 1$.

However, narrow banking will never be optimal in our environment, as long as investing in the production technology is actuarially favorable, *i.e.* $E[R] > 1$.

Proposition 1: A contract that eliminates runs through a policy of narrow banking will be worse than the bank's contract given by (13).

In our environment with banks, the expected return of holding the risky asset exceeds the return on holding storage. Therefore, if the risk is actuarially favorable, a von Neumann-Morgenstern expected utility maximizer will always hold positive amounts of the risky asset. Thus we have $h < 1$. It follows that a contract that specifies $h = 1$ will be suboptimal.

As we saw in the previous section, the bank can always eliminate financial crises by imposing the constraint (14). This constraint ensures no bank runs, while still allowing positive amounts of the risky asset, an obvious improvement in welfare.

Further, under narrow banking, financial intermediation loses its role in our environment. Under this rule, agents can achieve the same outcome in autarky, without the need for banks. This is because banks lose their intermediation function when they are not allowed to hold risky assets. It is also worth noting that the production technology will not be employed, consumption will be limited to the endowments, and no socially desirable additional output will be produced.

6 Suspension of Convertibility

In this section, we analyze a regime that allows suspension of convertibility. Under this policy, banks in period 1 will honor withdrawals from the first π share of consumers, after which they will suspend payments until the following period. Banks will offer to these first π consumers the fixed return c_1. In the following period, banks will offer the return c_2 to the remaining $(1-\pi)$ depositors. Notice that under this regime, liquidation never takes place. Thus, investments in the production technology are preserved, and no potential output is lost.

The sunspot equilibrium will be ruled out under suspension of convertibility, since this regime guarantees that resources will not be depleted by liquidation. Here, the threat of suspending payments is enough to prevent the run. Actual suspension of convertibility should never occur in equilibrium for high realizations of output.

On the other hand, for $R<R^*$, patient agents still have the incentive to misreport their type. In this case, suspension of convertibility will not prevent a fundamental run. The threat of suspending payments is not enough to deter agents from running, and suspension actually has to be implemented. This entails that an impatient agent faces the probability $(1-\pi)$ of being late in line when it reports to the bank. These impatient agents who arrive late in line will in fact receive no payment from the bank, and their consumption will be zero.

In contrast, patient agents who misreport their type, face the probability π of receiving c_1. However, with probability $(1-\pi)$ they arrive late, where they simply wait until the following period to withdraw c_2. Given this, the problem of the bank becomes

$$
\begin{aligned}
V^{sc} \equiv \; & \max \int_{r}^{R^*} \pi \left[\pi u(c_1)\right] + (1-\pi)\left[\pi \; u(c_1) + (1-\pi) \; u(c_2)\right] f(R) dR \qquad (15) \\
& + \int_{R^*} \left[\pi \; u(c_1) + (1-\pi) \; u(c_2)\right] f(R) dR
\end{aligned}
$$

subject to the deposit returns (4) and (5), and the threshold (6).

Consider a numerical example. Assume $u(c) = c^{1-\rho}/(1-\rho)$, with $\rho = 0.9$, and $F(R)$ to be a uniform distribution, with $\bar{R} = 3$, and $r = 0.3$. Further, assume $\pi = 0.5$, and $\phi = 0.01$.

Given these parameters, $V^{sc} = 10.0465$, while under full observation, $V^{fo} = 10.1994$. Accordingly, expected utility for suspension of convertibility does not attain the benchmark full observation case. Further, the contract banks can offer when no such policy is in place attains $V^{br} = 10.0541$. Thus, for our particular example, suspension of convertibility will reduce welfare relative to the equilibrium with bank runs. Whether suspension of convertibility is *ex ante* preferred to the contract with runs depends on the relative probabilities of runs. If the probability of sunspot runs is high enough, then suspension of convertibility will be preferred to bank runs. This is because suspension of convertibility rules out sunspots. If however, the probability of fundamental runs is relatively higher, then the environment with bank runs will be preferred. This is due to the fact that in the event of a fundamental run, a fraction of relocated agents will be left with zero consumption under suspension of convertibility. Whereas without suspension of convertibility, all agents received the same return.

Suspension of convertibility will prevent liquidation and rule out sunspot crises. However, it will not prevent fundamental runs and may increase the probability of a fraction of movers to be left with zero consumption.

7 Conclusion

We studied an environment where both sunspots and fundamental bank runs coexist. When we have a bank run, banks are forced to liquidate the long term investments. We then looked at two policies to improve on the outcome with runs. Narrow banking rules out multiple equilibria and implies a very safe banking system. Nevertheless, holding excessively high levels of liquidity will prevent socially productive investment opportunities, and thus may not be preferred to a contract with runs.

We find that a policy of suspension of convertibility, while preventing costly liquidation, may reduce welfare relative to a contract with runs, if the probability of sunspot runs is low enough. Since suspension of convertibility performs differently depending on what kind of run they face, the assessment of economic conditions that cause a financial crisis becomes critical. *Ex post*, if a bank run is caused by sunspots, then suspension of convertibility performs well. In contrast, when a bank run is caused by fundamentals, a policy of suspension of convertibility will not be optimal.

Further research could be done to try to address the implications of a lender of last resort policy in an environment where both types of crises coexist. To study this question, we would need an environment where money arises naturally, and where a monetary authority could lend currency to banks in the event of a liquidity shortage. We could combine this model with an environment that includes overlapping generations, such as Ennis and Keister (2003).

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