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Financial Crises in Developing Countries

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Financial Crises in Developing Countries

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To Regina, Aylen and Francisca

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Financial Crises in Developing Countries

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This dissertation provides both a theoretical and empirical look at financial crises in developing countries. The first chapter examines the effects that capital inflows have on the financial system in the context of a demand deposit banking model. In this environment, an adverse-selection problem arises where short-term capital has the incentive to enter the domestic banking system while long-term capital chooses to stay out. Then, short-term capital flows limit the risk-sharing function of banks. As short-term inflows increase, a threshold is reached beyond which it becomes optimal to restrict capital inflows. In addition, if the quantity of inflows is unknown, then banking crises occur as short-term inflows become large. In this case, the bank's insurance function is lost and assets have to be suboptimally liquidated. In spite of this, restricting capital inflows may not be optimal at all times, since the cost of doing so may be greater than the detriment of allowing them in.

The second chapter considers policy design in 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) are possible. Under this environment, policies of narrow banking and suspension of convertibility will not be optimal. In contrast, a lender of last resort mechanism, where a central bank lends currency to banks in the event of a run, achieves the optimal outcome by preventing costly liquidation of investments and optimally distributing risk when there are runs.

While the second chapter models both types of runs under one environment, the third chapter uses a multinomial logit model that differentiates both types of runs to study the factors associated with the emergence of financial crises. By doing this, important characteristics particular to each type of run come to light which are not accounted for by standard binomial logit specifications. We find evidence indicating that the two types of crises are indeed different, and are explained by different variables. Finally, by accounting for both types of crises, our results provide better support to existing self-fulfilling theoretical models.

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Chapter 1

Banks and Capital Inflows

1.1 Introduction

The past decade has seen many developing economies move towards opening their financial systems to unrestricted inflows and outflows of capital. With the increased liberalization and growth of these flows came a resurgence of financial crises, particularly in Latin America and Asia. At the center of these crises is the interaction between capital flows and financial intermediaries. In particular, short-term capital flows have been pointed out as being a crucial factor in causing financial distress[1]. This has renewed the discussion on the costs and benefits of restricting capital flows.

The goal of this paper is to specifically examine the effects that capital inflows have on domestic banks, and thus depositors, in the context of a demand deposit environment. The model is a two asset version of Diamond-Dybvig, where two types of agents, domestic and foreigners, are introduced. In this model, short-term capital inflows reduce bank's risk-sharing function. As short-term inflows increase, a threshold is reached beyond which it becomes optimal to restrict capital inflows. In addition, if the quantity of inflows is unknown, a banking crisis may occur as short-term inflows become large. In this case, both the insurance function is lost and assets have to be suboptimally liquidated. In

[1] See, for example, Rodrik and Velasco (1999).

spite of this, restricting short-term capital inflows may not be optimal at all times, since the cost of doing so may be greater than the cost of allowing crises to occur.

On the effect capital inflows have on banks, this paper is mainly related to the papers of Chang and Velasco (2001) and Goldfajn and Valdez (1998). Chang and Velasco develop an open economy version of Diamond and Dybvig (1983), where agents can borrow in international markets. In a demand deposit environment, a self-fulfilling bank run may occur when banks' potential short-term obligations exceed the liquidation value of its assets. They find that increased international borrowing by agents may exacerbate this potential illiquidity of banks and thus increase their vulnerability. In contrast, Goldfajn and Valdez (1998) model an economy with international depositors, where adverse productivity shocks may trigger a fundamental bank run. They find that intermediation of external funds increases the probability of crises, and magnifies capital outflows.

This analysis is also related to the literature on the insurance function of banks, in particular to the work of Jacklin (1987, 1993) and von Thadden (1997). Jacklin shows that the insurance function provided by demand deposit contracts disappears if trading opportunities are introduced. Von Thadden develops a model where time is continuous, and shows that if agents are allowed to withdraw and re-invest their funds, the insurance function may not be incentive compatible. He shows that, by introducing multiple assets, the moral hazard problem is eased.

My model is a two asset, open economy version of the Diamond-Dybvig model, where two types of agents are introduced. Agents are either domestic or foreign depositors. They have access to the same savings and production technologies, and share the same preferences, but differ only in the time they learn their idiosyncratic withdrawal demand. Domestic agents are the standard Diamond-Dybvig agent in the sense that they are uncertain about their liquidity needs at the time they deposit their endowments in banks. Foreign agents, on the other hand, know their liquidity preference at the time they are born. This paper then examines the effect that foreign agents have on entering the demand deposit contract[2].

Banks arise endogenously in this environment as a coalition of domestic agents to provide two services. They provide insurance among ex-ante identical agents who need to consume at different times, and they prevent suboptimal liquidation of assets. However, when banks are not able to distinguish domestic from foreign deposits, an adverse-selection problem arises. That is, short-term inflows have the incentive to join the financial system while long-term capital does not. Further, as short-term capital flows in, a moral hazard problem emerges, where foreigners exploit the bank's service of liquidity provision at the expense of domestic depositors. Implementing a self-selection constraint in this case fully thwarts liquidity provision, and thus may or may not be preferred, depending on the relative size of short-term flows.

In addition, if the quantity of capital flows is unknown, then a banking crisis occurs for sufficiently large short-term flows. In this case, both liquidity provision and prevention of costly liquidation are lost. A constraint that produces a separating contract will prevent banking crises. In spite of this,

[2] The application of this model is to capital inflows. However, more generally it can be seen as a banking model with two different types of agents, where the results are more widely applicable.

restricting short-term capital inflows may not be optimal at all times, since the cost of doing so may be greater than the expected loss in allowing crises to occur with positive probability.

The remainder of the paper proceeds as follows. Section 2 describes the environment and benchmark problem of the banks. The effect of short-term inflows on the domestic financial system when there is no aggregate uncertainty is discussed in section 3. In section 4 we assume aggregate uncertainty about withdrawal demand, as in Champ, Smith and Williamson (1996) and Smith (2002). Section 5 concludes.

1.2 THE MODEL

1.2.1 Environment

The model consists of an open economy populated by a continuum of agents. Time is discrete and there are three periods indexed by t=0, 1, 2. There are two types of agents, N^d domestic agents, and N^f foreigners. Both types are endowed one unit of a single good when young, and nothing in periods 1 and 2. Goods are freely traded across countries. Agents care only about consumption in periods 1 and 2, and are expected utility maximizers. Their utility has the form $U(c) = c^{(1-\rho)} \big/ (1-\rho)$, with the coefficient of relative risk aversion ρ>1.

Domestic and foreign agents differ only in the time they learn their liquidity preference shock. Local agents learn their need of liquidity after the portfolio decision is made, and thus are the classic Diamond-Dybvig agent. Let N_1^d and N_2^d be the share of domestic impatient and patient agents, respectively, with $N_1^d + N_2^d = 1$. There is no aggregate uncertainty for the total population nor the share of domestic impatient and patient agents.

In contrast, foreigners know at the time they are born whether they will prefer to consume in periods 1 or 2. We label N_1^f, N_2^f as the total population of impatient and patient foreigners, respectively[3]. Agents' type, domestic or foreigner, is observable. However, the liquidity preference shock is private information for both types of agents.

Both types of agents have access to a linear production technology whereby one unit of the good invested in period 0 yields $R>1$ units of the good at time 2. This technology is illiquid, in the sense that an investment that is interrupted in period 1 generates $r<1$ units of consumption. In addition, there is a liquid storage technology, whose return is equal to 1 in both periods. In this sense, the liquid asset dominates the production technology in the short-term, while investing in the production technology dominates the liquid asset in the long-term.

The timing of events follows. At the beginning of period 0, young agents receive their endowments, and foreigners learn their liquidity preference. Agents then choose their portfolio allocation, i.e. the mix of storage and the illiquid investment. In period 1, domestic agents learn whether they will consume in periods 1 or 2. Following this, period 1 consumption occurs, where the illiquid

[3] Alternatively, we can think of the N_1^f foreigners as Diamond-Dybvig agents with a larger share of impatient agents relative to domestic agents, where here we look at the limiting special case where all are impatient. Likewise, the N_2^f foreigners have a lower probability relative to locals of becoming impatient, set at the limit at zero.

technology may be liquidated in order to be consumed. In period 2 the long-term investment technology matures, and patient agents consume.

1.2.2 Bank Behavior

Banks arise endogenously in our environment as a coalition of domestic agents. This is because domestic agents benefit from pooling their resources in order to overcome idiosyncratic uncertainty, and they gain from insuring themselves against their liquidity preference shock. In contrast, foreign agents face no uncertainty at the time the investment decision is made, and thus have no need to pool their resources nor require insurance. In this sense, banks arise naturally as domestic banks that care about domestic agents.

Given this, domestic banks will offer a contract that maximizes the expected utility of local agents. Banks announce contracts in period 0, which specify returns to depositors that depend on their liquidity preference (early vs. late-withdrawers) reported by agents. After young agents deposit their endowments with banks, banks use these deposits to save in the liquid asset and make investments in the production technology. In period 1, domestic depositors learn whether they will withdraw in period 1 or 2. Following this, banks pay to agents who wish to withdraw early. In period 2 the long-term investment matures, and banks dispense payments to the patient agents.

Here we do not impose a sequential service constraint, so that self-fulfilling banking crises are ruled out. Banks are able to observe the quantity of early-withdrawers in period one before they make payments. This implies that that if all agents choose to withdraw early, banks will be able to liquidate resources and divide them equally among agents, so that no agent may be left without consumption. Thus, it will never be optimal for a patient agent to run, and a self-fulfilling run is not an equilibrium.

Let k denote the share of bank's investments in the production technology, and m denote the share of liquid reserves. Thus, banks will face the constraint

$$m + k = 1 \tag{1.1}$$

Assume initially a separated world. Recall that agents' type, whether they are locals or foreigners, is observable, and assume that agents are allowed to deposit only one unit per person. Given this, banks will be able to offer a contract to domestic agents only, where foreigners are not allowed to participate. Let c_1^d and c_2^d be consumption for domestic early and late withdrawers, respectively. Then, the problem of the bank is

$$V^d = \max_{c_1^d, c_2^d} \; N_1^d \, U(c_1^d) + (1 - N_1^d) \, U(c_2^d) \tag{1.2}$$

subject to

$$N_1^d c_1^d = m \tag{1.3}$$

$$(1 - N_1^d) c_2^d = R(1 - m) \tag{1.4}$$

$$c_2^d \geq c_1^d \tag{1.5}$$

$$V^d > V^a \tag{1.6}$$

$$c_1^d, c_2^d \geq 0$$

Where (1.3) and (1.4) are the resource constraints, and (1.5) is the incentive compatibility or truth-telling constraint for domestic agents. (1.6) is the participation constraint of domestic agents, where V^a is the indirect utility of domestic agents behaving in autarky. Given constant relative risk aversion preferences, the solution to this problem sets the share of liquid reserves as

$$m^d = \frac{N_1^d}{N_1^d + (1 - N_1^d) R^{(1-\rho)/\rho}} \tag{1.7}$$

and the return schedule for locals becomes

$$
\begin{cases}
c_1^d = \dfrac{1}{N_1^d + (1 - N_1^d) R^{(1-\rho)/\rho}} \\
c_2^d = \dfrac{R^{(1/\rho)}}{N_1^d + (1 - N_1^d) R^{(1-\rho)/\rho}}
\end{cases}
\tag{1.8}
$$

Foreign agents, in contrast, are able to achieve their optimal outcome without the need for banks. Young foreigners that know that they will want to withdraw in the first period, can simply acquire the liquid asset, while foreign late-withdrawers can invest all of their endowment in the illiquid technology in order to realize the higher return. Thus, consumption for foreigners will be

$$
\begin{cases}
c_1^f = 1 \\
c_2^f = R
\end{cases}
\tag{1.9}
$$

where c_1^f and c_2^f are consumption for foreign impatient and patient agents, respectively.

Local depositors choose to deposit all of their endowments in banks, since the expected utility of an agent whose funds are intermediated will be greater than the expected utility when they behave autarkically, i.e. $V > V^a$. This is because financial intermediation in this model provides two services[4].

First, banks prevent suboptimal holding of assets. When local depositors behave autarkically, their consumption becomes $c_1^d = m + r(1 - m) < 1$ and $c_2^d = m + R(1 - m) < R$. In period 1 the long-term asset is liquidated at cost, and in period 2 the short-term asset is held suboptimally. In contrast, banks are able to avoid this by pooling depositors and, by applying the law of large numbers, allocating the exact share of endowments to liquid reserves that will be withdrawn. This implies that no reserves need to be held between periods, and no long-term investments need to be terminated early. A coalition of agents

[4] Bencivenga and Smith (1991) first introduce two assets in an OG-Diamond-Dybvig environment and discuss these two services, and their effect on growth.

takes advantage of the law of large numbers, and is able to offer $c_1^d = 1$ and $c_2^d = R$. Notice that this is identical to (1.9), the solution for foreigners. For this instance it is particularly clear to see that a coalition of agents completely resolves the idiosyncratic uncertainty about the timing of consumption, which is the distinction between both types of agents. Notice that this service is somewhat different from risk-sharing, since it ex-post benefits both early- and late-withdrawers, and comes at no cost to agents.

Second, banks provide insurance should agents become early withdrawers. That is, for risk aversion greater than one, we have from (1.8) that $c_1^d > 1$. This is achieved at the cost of foregoing some consumption if they are late-withdrawers, where $c_2^d < R$, also by (1.8). This risk-sharing service that is realized through financial intermediation is what Diamond and Dybvig define as banks providing liquidity.

Finally, notice that the higher the level of risk aversion, the more agents value liquidity provision. This can be seen by noting that $\frac{\partial m}{\partial \rho} > 0$. As risk aversion increases, in the limit we have $c_1^d = c_2^d$, where agents choose to fully insure against early consumption.

1.3 Capital Inflows

In this section we examine the case when foreign agents cannot be prevented from depositing their endowments in banks under the contract offered to domestic agents, if they wish to do so. We accomplish this by assuming that banks are not able restrict deposits to one unit per agent. Therefore, even if foreigners are discernable from domestic agents, if there are gains from depositing in a local bank, foreigners can offer to share the profits with a domestic agent that is willing to deposit for them. Given this, the problem of a domestic bank now becomes

$$V^* = \max_{c_1, c_2} \; N_1^d U(c_1) + (1 - N_1^d)\, U(c_2) \tag{1.10}$$

subject to

$$\lambda c_1 = m \tag{1.11}$$

$$(1-\lambda)c_2 = R(1-m) \tag{1.12}$$

$$c_2 \geq c_1 \tag{1.13}$$

$$V^* > V^a \tag{1.14}$$

$$(c_1 - 1)(N_1^f - \phi_1^f) \leq 0 \tag{1.15}$$

$$(c_1 - 1)\phi_1^f \geq 0 \tag{1.16}$$

$$(c_2 - R)(N_2^f - \phi_2^f) \leq 0 \tag{1.17}$$

$$(c_1 - 1)\phi_2^f \geq 0 \tag{1.18}$$

$$c_1, c_2 \geq 0\,, \quad 0 \leq \phi_1^f \leq N_1^f\,, \quad 0 \leq \phi_2^f \leq N_2^f$$

where λ is the endogenous share of total impatient depositors given by

$$\lambda = \frac{N_1^d + \phi_1^f}{N_1^d + N_2^d + \phi_1^f + \phi_2^f} \tag{1.19}$$

In this problem, domestic banks decide whether to allow foreign agents to enter by way of choice of the consumption schedule. This is described by the constraints (1.15) to (1.18) which are the participation constraints of foreign agents. Together, (1.15) and (1.16) indicate that if $c_1 \leq 1, \Rightarrow \phi_1^f = 0$, and if $c_1 > 1, \Rightarrow \phi_1^f = N_1^f$ for foreign impatient agents. Similarly, (1.17) and (1.18) satisfy $c_2 \leq R, \Rightarrow \phi_2^f = 0$ and $c_2 > R, \Rightarrow \phi_2^f = N_2^f$ for foreign patient agents[5].

[5] Truly, when $c_1 = 1, \Rightarrow \phi_1^f \in [0, N_1^f]$, where foreigners are indifferent between entering or not. In this case we assume for simplicity that they do not enter, via a "boat-trip" cost ε >0 of coming from overseas.

Before we get to the solution to (1.10), we can simplify the problem by ruling out participation of patient foreigners.

Lemma 1.1: $\phi_2^f = 0$ *for* $\rho > 1$.

Proof: See appendix A.

Lemma 1.1 says that patient foreigners will never have the incentive to enter the banking contract in equilibrium. In contrast, impatient foreigners may have the incentive to enter, depending on the value of c_1 chosen by banks. This is due to the fact that the income effect dominates the substitution effect for domestic agents when $\rho > 1$. It entails that early consumption will be greater or equal to one, and by feasibility, late consumption will be less than or equal to R. Thus, patient foreigners prefer not to enter, since their return in autarky equals R. In this sense, an adverse-selection problem arises, where short-term capital may have the incentive to enter while long-term capital decides to stay out of the domestic financial system.

Given this, we turn our attention to the bank's problem where only short-term capital may want to enter the domestic contract. Consider first the pooling case where banks opt to let foreign short-term capital enter, that is $\phi_1^f = N_1^f$. In this case, the solution to (1.10) sets the optimal reserve ratio as

$$m^p = \frac{1}{1+\left(\frac{(1-N_1^d)}{N_1^d}\right)^{1/\rho}\left(\frac{(1-\lambda)}{\lambda}\right)^{(\rho-1)/\rho} R^{(1-\rho)/\rho}} \tag{1.20}$$

However, local agents may prefer a contract that gives foreign impatient agents the incentive not to deposit in banks. Consider the separating case where $\phi_1^f = 0$. This implies from the participation constraint (1.15) that period 1 consumption needs to be set to $c_1 \leq 1$. It follows that by the resource constraint (1.11) and the first order condition, the solution sets

$$m^s = N_1^d \tag{1.21}$$

Proposition 1.1: Define the threshold

$$\hat{N}_1^f = N_1^d(R^{\rho-1} - 1) \tag{1.22}$$

Then the solution to the bank's problem given by (1.10) *is the contract* (c_1, c_2) *given by*

$$\left.\begin{aligned} c_1 &= \tfrac{1}{\lambda} m^p \\ c_2 &= \tfrac{R}{(1-\lambda)}(1 - m^p) \end{aligned}\right\} \text{ for } N_1^f \leq \hat{N}_1^f$$
$$\left.\begin{aligned} c_1 &= 1 \\ c_2 &= R \end{aligned}\right\} \text{ for } N_1^f > \hat{N}_1^f \tag{1.23}$$

Proof: see appendix A.

The solution to the bank's problem given in proposition 1.1 portrays the tradeoff between the bank's contract providing liquidity and the loss of resources to foreigners who exploit this service. For a small enough share of foreign agents, domestic agents will prefer the loss of transferring some resources to foreigners rather than give up the service of liquidity provision. Conversely, for shares of foreign impatient agents greater than $\hat{N}_1^f$, agents prefer the self-selection outcome. Here the cost of subsidizing foreigners' consumption exceeds the benefits of liquidity provision, so separation is chosen.

When domestic agents implement a risk-sharing contract, they redistribute resources from late to early-withdrawers. Thus, when foreign early-withdrawers enter this contract, they are receiving transfers from domestic late-withdrawers.

This unintended transfer of goods from local to foreign depositors reduces the welfare of domestic agents.

In addition, as the share of early-withdrawers increases, banks allocate a bigger share of deposits to the liquid asset, and less to the higher yielding production technology. Thus, banks are able to provide less insurance to impatient agents as their share increases. In this sense, short-term inflows reduce liquidity provision.

Notice that the threshold $\hat{N}_1^f$ given by (1.22) is increasing in N_1^d, ρ and R. That is, when N_1^d is large, then a bigger share of agents benefits from liquidity provision and thus they are less willing to give it up. Also, the higher the degree of risk aversion, the more agents value liquidity provision, and thus are less willing to sacrifice this insurance function of banks. Finally, the higher the return on the production technology, the higher intertemporal transfers, and thus the threshold at which domestic agents are willing to give up provision of liquidity is raised.

Lastly notice that while liquidity provision is reduced in the pooling case, or is completely lost for the separating case, domestic agents still prefer to deposit their endowments in banks. This is so since the other service banks provide, preventing suboptimal asset holding, is still achieved. However, as r→1, $V^* \rightarrow V^a$ for $N_1^f > \hat{N}_1^f$. That is, as the potential cost of holding the production technology disappears, banks lose their role when they do not provide liquidity.

1.4 UNKNOWN CAPITAL INFLOWS

In this section we assume aggregate uncertainty about withdrawal demand, as in Champ, Smith and Williamson (1996) and Smith (2002). In particular, we assume that the quantity of foreign agents, N_1^f is now a random variable whose realization is unknown at the time banks make the portfolio decision. Finally, individual foreign agents know whether they are impatient or not at the time they choose to deposit, but the aggregate share of impatient agents is unknown to banks.

The timing of events follows. Banks announce contracts in period 0. Based on the contract banks offer, both foreign and domestic agents choose whether to deposit or not. Banks then choose the portfolio allocation. After domestic depositors learn their type, both domestic and foreign agents who wish to withdraw early report to banks, at which time N_1^f is revealed. Following this, banks pay to agents based on this new information. In period 2 the production technology matures, and banks dispense payments to the remaining patient agents.

As in the previous section, foreign patient agents will never find it optimal to deposit in banks for $\rho>1$. Define $N_1 = \frac{N_1^d + N_1^f}{N_1^d + N_2^d + N_1^f}$ as the total share of impatient agents, its value drawn from a distribution $G(N_1)$ with pdf $g(N_1)$, which is common knowledge, and with finite support in the interval $[N_1^d,1]$. Then, the bank's problem is given by

$$\tilde{V} = \max_{\substack{c_1(N_1), c_2(N_1) \\ \alpha,\, \delta}} \int_{N_1^d}^{1} \Big[N_1^d\, U(c_1) + (1 - N_1^d) U(c_2) \Big] g(N_1)\, dN_1 \tag{1.24}$$

subject to

$$\lambda c_1 = \alpha\, m + \delta\, r (1 - m) \tag{1.25}$$

$$(1-\lambda)c_2 = (1-\alpha)m + (1-\delta)R(1-m) \tag{1.26}$$

$$c_2 \geq c_1 \tag{1.13}$$

$$\tilde{V} > V^a \tag{1.27}$$

$$(c_1 - 1)(N_1^f - \phi_1^f) \leq 0 \tag{1.15}$$

$$(c_1 - 1)\phi_1^f \geq 0 \tag{1.16}$$

$$c_1, c_2 \geq 0\,,\ \ \alpha, \delta \in [0,1]\,,\ \ 0 \leq \phi_1^f \leq N_1^f$$

where α and δ represent the fraction of liquid reserves and investments, respectively, that banks liquidate in period one. They capture the fact that there is aggregate uncertainty, so banks at times may hold liquid reserves across periods or may have to scrap investments in order to meet liquidity needs of early withdrawers.

Consider first the pooling case where foreign patient agents choose to deposit. Here we have $\lambda = N_1$, which implies aggregate uncertainty.

Proposition 1.2: The pooling contract to the problem with aggregate uncertainty can be described by the optimal return schedule

$$\begin{aligned}
&c_1 = c_2 = m + R(1-m) && \text{for} \quad N_1 \in (N_1^d, \underline{N}_1) \\
&\left.\begin{aligned} c_1 &= \tfrac{1}{\lambda} m \\ c_2 &= \tfrac{R}{(1-\lambda)}(1-m) \end{aligned}\right\} && \text{for} \quad N_1 \in (\underline{N}_1, \bar{N}_1) \\
&\left.\begin{aligned} c_1 &= \tfrac{1}{\bar{N}_1} m \\ c_2 &= \tfrac{R}{r}\tfrac{1}{\bar{N}_1} m \end{aligned}\right\} && \text{for} \quad N_1 \in (\bar{N}_1, 1)
\end{aligned} \tag{1.28}$$

where $\underline{N}_1 = \frac{m}{m+(1-m)R}$, $\bar{N}_1 = \frac{m}{m+(1-m)r}$, and the optimal reserves ratio m is defined by the first order condition

$$\begin{aligned}
&(1-R)(m + R(1-m))^{-\rho}\, G(\underline{N}_1) + \int_{\underline{N}_1}^{\bar{N}_1} \Big[N_1^d N_1 \left(\tfrac{m}{N_1}\right)^{-\rho} - (1-N_1^d)\tfrac{R}{(1-N_1)}\left(\tfrac{R(1-m)}{(1-N_1)}\right)^{-\rho} \Big] g(N_1)dN_1 \\
&(1-r)\big[N_1^d (m + r(1-m))^{-\rho} - (1-N_1^d)\tfrac{R}{r}\big(\tfrac{R}{r}(m + r(1-m))^{-\rho}\big)\big]\big[1 - G(\bar{N}_1)\big] = 0
\end{aligned} \tag{1.29}$$

Proof: See Appendix A.

As we can see from the optimal return schedule, banks provide full insurance for withdrawal demand in $(N_1^d, \underline{N}_1)$. Here, $\alpha<1$ and some cash reserves will be forwarded to the next period. For withdrawals in $(\underline{N}_1, \bar{N}_1)$, cash reserves are exhausted, and impatient get lower returns than patient agents. However, $\delta=0$ so that no early liquidation of the production technology is carried out. Lastly, when withdrawal demand exceeds $\bar{N}_1$, $\delta>0$ where banks interrupt the production process in order to satisfy early withdrawals. We consider it a banking crisis when the share of early withdrawers is large enough so that cash reserves are depleted and output losses take place.

Proposition 1.2 also shows that for realizations of $N_1 \in (N_1^d, \underline{N}_1)$, where no crisis occurs, foreigners receive transfers from domestic agents. When cash reserves are exhausted, for $N_1 \in (\underline{N}_1, \bar{N}_1)$, foreigners may exploit liquidity provision, as long as the realization of N_1 is less than the optimal reserve ratio *m*. Finally, when a full fledged crisis occurs, foreigners receive lower returns compared to when they do not enter.

Similar to the case where the share of capital flows is known, expected utility of local depositors is reduced as foreigners enter the banking contract. In particular, this is so for two reasons. First, as we just discussed, domestic agents that value liquidity provision end up transferring resources to foreign agents for low realizations of N_1. Second, here the uncertainty of withdrawal demand potentially forces both assets to be used sub optimally. That is, liquid assets may be held inefficiently across periods, or the production technology may be liquidated early. Further, for $N_1 \in (\bar{N}_1, 1)$, both services that banks provide, liquidity provision and prevention of costly liquidation, are lost.

Here again, it is feasible for domestic banks to choose a separating contract where $\phi_1^f = 0$ by satisfying $c_1 \leq 1$. Here, foreign agents choose not to enter, and thus we have $\lambda = N_1^d$. It follows that the term in brackets in (1.24) can be pulled out of the integral, since there is no longer aggregate uncertainty when foreigners do not enter. Also by no aggregate uncertainty, we have α=1 and δ=0, where assets are held optimally.

The contract where agents self-select comes at the cost of losing the service of liquidity provision but allows for the other service of banks, which is the optimal intertemporal holding of assets. In contrast, the pooling contract will not be able to prevent suboptimal holding of assets, and may or may not be able to provide insurance. That is, for low quantities of short-term capital inflows it will provide insurance, but will not be able to for large quantities of unpredicted capital inflows.

Then, for certain parameters, domestic agents will ex-ante prefer the pooling contract where foreigners are not screened, and banking crises may exist. Then, if we define $\tilde{V}^p$ and $\tilde{V}^s$ as the values to the pooling and separating indirect utilities for the problem given in (1.24), the solution must satisfy $\tilde{V} = \max\left\{\tilde{V}^p, \tilde{V}^s\right\}$.

To illustrate this welfare tradeoff between pooling and separating equilibria, consider a representative example of the model. Specifically, assume a uniform distribution $G(N_1)$ with pdf $g(N_1) = 1/(1 - N_1^d)$, and consider the following parameters. The coefficient of relative risk aversion is ρ=3, the share of domestic impatient agents is $N_1^d = 0.5$ and the return to investments, are R=2 and r=0.5. Given these parameters, the indirect utilities are $\tilde{V}^p = -0.326$ and $\tilde{V}^s = -0.313$. It follows that the separating contract is chosen. In contrast, if we increase the return to investments to R=3, leaving all other parameters unchanged, we get $\tilde{V}^p = -0.277$ and $\tilde{V}^s = -0.278$, where the pooling contract is preferred. Similarly, keeping R relatively low but increasing the coefficient of relative risk aversion ρ, will raise the threshold at which the pooling contract will be chosen.

1.5 CONCLUSION

This paper attempts to study the effects that capital inflows have on the financial system in the context of a demand deposit banking model. In this environment, banks arise as a coalition of domestic agents to resolve the inefficiencies caused by idiosyncratic uncertainty, and to insure agents against the unwelcome situation of turning out to be an early withdrawer. When banks can't distinguish domestic from foreign deposits, short-term foreign capital has the incentive to enter the banking contract to take advantage of the insurance service that domestic banks provide. As capital inflows become large, the cost of allowing capital inflows exceed the benefits provided by insurance, and a separating contract is preferred. Further, if the quantity of inflows is unknown, then a banking crisis caused by excessive short-term capital inflows may occur. In this case, the services that banks provide may be lost. In spite of this, restricting short-term capital inflows may not be optimal at all times, since the cost of doing so may be greater than the expected loss in allowing crises with positive probability.

Chapter 2

Optimal Policy with Both Sunspot and Fundamental Bank Runs

2.1 Introduction

A new surge of banking crises has emerged since the 1980's in developing countries. The severe consequences to the economies that suffered these crises have been widely documented[6]. 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), and Peck and Shell (2002). While one literature views the banking crisis as a consequence of poor macroeconomic performance, the other views it as the actual cause of macroeconomic downturns.

The results of empirical work on the causes of banking crises have been mixed. Gorton (1988) and Calomiris and Gorton (1991) examine panics during

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[6] See, for example, Caprio and Klingebiel (1997).

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. In contrast, Boyd, Gomis, Kwack and Smith (2001) look at banking crises across countries covering the period from 1970 to 1998. Boyd et al note that "all banking crises are not created equal." Their findings suggest that it is more the exception than the rule that there are any unusual macroeconomic events that cause banking crises. Thus, banking crises may often be the outcome of bad realizations of sunspot equilibria. It therefore appears possible that fundamental and sunspot crises may not be mutually exclusive, but each may best represent distinct states of the world.

This paper constructs an environment 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 policy design in a banking model where both types of runs are possible. As in Champ, Smith and Williamson (1996) and Antinolfi, Huybens and Keister (2001), we consider an economy where spatial separation and limited communication coupled with random relocation generate a natural role for money, and preclude equity contracts from arising. Introducing monetary considerations into banking models seems vital since bank runs involve currency in a central way. It will also allow for a more careful discussion of monetary policy.

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 of investments 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.

Nevertheless, the presence of bad equilibria present room for improvement, especially if compared to the benchmark environment where costly asset liquidation is prevented. It therefore becomes of interest to examine the effects that safety net mechanisms may have in this model. Specifically, we look at policies of narrow banking, suspension of convertibility and lender of last resort.

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 acting as intermediaries.

Suspension of convertibility involves banks suspending payments until the next period once their currency reserves are depleted. Similar to narrow banking, suspension of convertibility is a tool that could be applied directly by banks without the explicit need of a monetary authority. However, central banks often regulate on the use of such a rule, and in particular do not allow banks to use it at their own discretion. Central banks often retain the right to suspend troubled banks, or dictate banking holidays for the entire banking system. 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 policy 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.

In contrast, a policy where a monetary authority lends currency to banks in the event of a liquidity shortage may achieve the optimal outcome. In this manner, banks will be able to preserve the long term investments and thus endure bank runs. Under this policy, and similar to suspension of convertibility, sunspot runs will be prevented while fundamental runs will still occur. Nevertheless, this monetary policy will realize the benchmark outcome by optimally distributing risk when there are runs. When a fundamental run takes place, the elastic supply of money will accommodate agents' demand for liquidity, and consumption will be optimally adjusted without the need of costly liquidation. In addition, if the central bank targets the discount window rate to be equal to the inverse of the inflation rate, then this policy will not be inflationary. Further, the central bank needs only to follow a simple rule, and in particular it does not require any knowledge on realizations of output or banks' holdings of reserves.

Since the policies discussed in this paper perform 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 both suspension of convertibility and lender of last resort mechanisms will perform equally well. In contrast, when a bank run is caused by fundamentals, a policy of suspension of convertibility will not be optimal, whereas a lender of last resort monetary policy will attain the optimal outcome.

Proposals have been made in a number of countries to either establish a currency board or implement dollarization. To the extent that these policies limit the capacity of a monetary authority to act as a lender of last resort, they will curtail its ability to respond to banking crises.

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 lender of last resort policy, while section 6 examines suspension of convertibility. Section 7 concludes.

2.2 THE MODEL

2.2.1 Environment

The model consists of an overlapping generations, discrete time, infinite horizon environment populated by a sequence of people who live for two periods. At each date, young agents are born in one of two locations, each location consisting of a continuum of agents with unit mass. Agents are endowed with y units of the single good in the economy when young, which is constant over time. Preferences are given by $U(c_{t+1})$, that is, each agent derives utility from consumption when old only. Assume $U(\cdot)$ to be strictly concave, with $U(0)=0$. In addition, agents face a probability π of being relocated when old. The fraction π of relocated agents is known and constant over time. However, the relocation shock is private information to the individual agents. There is limited communication between locations, thus trade can only occur between agents in the same location. This precludes equity contracts from arising and generates a transaction role for money. Relocated agents are going to use money to purchase consumption goods once they move. In addition to money, there is a production technology that generates R_{t+1} per unit of input invested in period t. R_{t+1} is assumed to be an *i.i.d.* random variable with distribution function $F(R)$, which is common knowledge and constant over time. Further, $\int R_{t+1} f(R)\,dR > 1$, with the lower bound on returns, $\underline{R} < 1$. However, if the production technology is liquidated in the same period, then it will yield a return r. We assume $r = \underline{R}$. This is to say that liquidating investments will always be costly. Liquidation occurs before relocation; therefore relocated agents are able to transport the liquidated goods across locations.

Both agents and banks are assumed to observe at the end of the first period the return to the illiquid investment, R_{t+1}. This update in information may change agents' incentives, where non-movers will have the incentive to misreport their type for low realizations of investment returns. Thus, agents will have the incentive to run on banks based on a low realization of output[7]. We denote this scenario as a fundamental bank run. Banks also observe next period's returns, thus they are able to foresee when all agents are about to withdraw. Banks predict withdrawals, but are not able to differentiate movers from non-movers. Thus, the best they can do is to offer all agents the same amount of consumption.

Also at the end of the first period, all agents, but not banks, observe the realization of an extrinsic random variable. This random variable is completely unrelated to the fundamentals of the economy, but it 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. Since banks are assumed not to

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

observe the sunspot variable, they are not able to predict agents' actions based on sunspots. The fact that banks can't predict such a panic, implies that in this case they will not be able to offer all agents the same amount of consumption.

The timing of events follows: At the beginning of the first period, young agents receive endowments and deposit them in banks. Banks then choose their portfolio allocation, i.e. the mix of currency and the illiquid investment. At the end of the first period, a fraction π of agents learns that that they will be relocated. Simultaneously, next period's R becomes public, and agents observe a sunspot variable s. Following this, banks pay to agents that report to be movers. At the beginning of the second period, relocation occurs. R_{t+1} is realized, and banks dispense payments to the agents that remained in the same location. Old agents that hold currency trade it for goods with banks, which demand currency and supply goods as part of the portfolio allocation of the $t+1$ young. Lastly, consumption occurs.

Let M_t and p_t denote the time t per capita money supply and price level, respectively. Then we can define $z_t \equiv M_t/p_t$ as the outstanding stock of real balances at time t. The money supply grows at the exogenously set gross rate σ, with the initial money supply $M_0 > 0$, given. Thus the government budget constraint will be $\tau_t = [(\sigma - 1)/\sigma] \quad z_t$. Government revenues are then transferred to young agents in a lump-sum manner. The gross real rate of return on money balances is then p_t/p_{t+1}. We further assume that $r < p_t/p_{t+1}$, so that scrapping investments does not dominate the use of reserves, and $p_t/p_{t+1} < \int R_{t+1} f(R)\, dR$, so that investments dominate reserves for sufficiently low levels of risk aversion.

2.2.2 Financial Intermediation

Banks announce contracts, which specify returns to depositors that depend on the type (movers vs. non-movers) reported by agents. Banks are assumed to be profit maximizers. However, since banks operate in a perfectly competitive environment, they will offer a contract that maximizes the expected utility of agents subject to banks telling the truth. After young agents deposit their endowments with banks, banks use these deposits to acquire currency reserves from old agents and to make investments in the production technology. Finally, banks operate in a single location, that is, they accept deposits and invest only in their own location.

2.3. 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_{t+1} and when banks' currency reserves are depleted. Also, banks are not allowed to suspend cash payments nor borrow funds from a monetary authority.

2.3.1 No Runs

After each young agent deposits their endowment y, banks use these deposits to obtain money and to invest in the illiquid technology. Let i_t denote the real value of the illiquid investment and h_t denote the real value of cash reserves. Thus, banks will face the constraint

$$h_t + i_t = y + \tau_t \tag{2.1}$$

Banks will offer a gross real return to movers c^m and a return to non-movers c. The π relocated agents can be given only currency and the proceeds of the liquidated investment. Let δ denote the fraction of the investment that is liquidated in period one, and α be the fraction of currency that banks carry over to the next period. Then, the bank's resource constraints can be written as:

$$\pi c^m_{t+1}(y + \tau_t) = (1-\alpha)\frac{p_t}{p_{t+1}} h_t + \delta r i_t \tag{2.2}$$

$$(1-\pi)\, c_{t+1}(y + \tau_t) = \alpha \frac{p_t}{p_{t+1}} h_t + (1-\delta) R_{t+1}\, i_t \tag{2.3}$$

When agents do not run on banks, banks find it optimal to set δ equal to zero, since the return on liquidating investments is assumed to be dominated by the return on holding money. The optimal fraction of currency banks hold across periods, α, will be equal to zero for low levels of risk aversion, since the return on money holdings is dominated by the expected return on holding investments. Thus, cash reserves will optimally be exhausted and no costly liquidation will occur when there are no runs. Finally, if we define $m_t \equiv h_t/(y + \tau_t)$, then the deposit returns in a no-run outcome can be written as:

$$c^m_{t+1} = \frac{1}{\pi}\frac{p_t}{p_{t+1}} m_t \tag{2.4}$$

$$c_{t+1}(R_{t+1}) = \frac{R_{t+1}}{(1-\pi)}(1 - m_t) \tag{2.5}$$

Lemma 2.1: When agents do not run on banks, banks will offer a contract given by the deposit returns c^m_{t+1} *and* $c_{t+1}(R_{t+1})$ *.*

Proof: See appendix B.

Equations (2.4) and (2.5) depict the standard deposit contract assumed in the Diamond-Dybvig literature, where the liquid asset is money. Notice that the return to non-movers $c_{t+1}(R_{t+1})$ is a random variable, since it depends on R_{t+1}, unknown at the time banks choose their portfolio allocations.

2.3.2 Low Output

The randomness of the return to non-movers $c_{t+1}(R_{t+1})$ implies that the relation of the returns to non-movers versus movers will depend on the random variable R_{t+1}. In particular, we can write the output threshold for which $c^m_{t+1} = c_{t+1}(R_{t+1})$ as,

$$R^*(m) = \frac{(1-\pi)}{\pi}\frac{p_t}{p_{t+1}}\frac{m_t}{(1-m_t)} \tag{2.6}$$

For realizations of $R_{t+1} > R^*(m)$, the return for non-movers will be greater than the return for movers, and the bank problem may be as discussed above. However, for realizations of $R_{t+1} < R^*(m)$, the return c^m_{t+1} will be greater than the return $c_{t+1}(R_{t+1})$. Recall that both agents and banks observe the prospective return R_{t+1} simultaneously to agents learning π and before they report to banks. Thus, if non-movers learn that R_{t+1} will be less than $R^*(m)$, then they will have the incentive to pretend to be movers. Since banks do observe R_{t+1}, they are able to correctly predict agent's actions. Because of this, banks are capable of offering all agents the same amount of consumption, thus overcoming the sequential service constraint. Given this, banks can institute a deposit return of

$$c^c_{t+1}(R_{t+1}) = \frac{p_t}{p_{t+1}}m_t + R_{t+1}(1-m_t) \tag{2.7}$$

that will be paid to all agents in the event of $R_{t+1} < R^*(m)$.

Lemma 2.2: When banks observe $R_{t+1} < R^*(m)$, *they will offer a deposit return* $c^c_{t+1}(R_{t+1})$ *to all agents, and no bank run will occur.*

Proof: See appendix B.

When $R_{t+1} < R^*(m)$, banks will pay $c^c_{t+1}(R_{t+1})$ to all agents. Banks will pay in currency to movers and forward the remaining cash to the next period, where it will pay non-movers a mix of currency and the returns on the production technology. That is, all agents achieve the same amount of consumption, where movers receive only currency which they can carry to the other location, and non-movers are given a mix of currency and goods. Here, non-movers will truthfully report their type, since they gain no additional consumption by pretending to be movers. Agents *ex ante* will prefer a risk sharing contract when a low realization of output occurs. Thus, they will accept a contract contingent on the signal on R_{t+1}, since they are able to observe such a signal.

2.3.3 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 withdraw early 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 currency reserves, they can offer to the remaining (1-π) share of agents a return low enough so that no agent late in line will be left without consumption. In particular, they can offer to the remaining (1-π) agents the return

$$c_{t+1}^{r} = \frac{r}{(1-\pi)}(1-m_t) \tag{2.8}$$

Lemma 2.3: When banks observe a fraction greater than π reporting to be movers, they will offer a deposit return c_{t+1}^{r} to all remaining agents. Then, no sunspot panic will occur.

Proof: see appendix B.

Under this rule, a sunspot run is not an equilibrium, since a potential payoff of c_{t+1}^{r} ensures that no agent would be left without consumption if all other non-relocated agents chose to run. This means that a non-relocated agent who chooses not to run will get a payment of $c_{t+1}(R_{t+1}) > c^r_{t+1}$ if it chooses to wait until next period, regardless of what other agents choose to do. Further, the *ex ante* expected utility for non-movers when they choose to run will always be less than their expected utility when they truthfully report their type. Hence a threat of paying c^r_{t+1} 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 a payment of c^r_{t+1} once a fraction greater than π reports to be movers, since they are able to verify banks claims of depleted currency reserves.

2.3.4 The Bank's Problem

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

$$\max \int_{\underline{R}}^{R^*(m)} U(c^c_{t+1})\, f(R)\, dR \;+\; \int_{R^*(m)}^{\bar{R}} \Big[\pi\, U(c^m_{t+1}) + (1-\pi) U(c_{t+1})\Big] f(R)\, dR \tag{2.9}$$

subject to the deposit return schedules (2.4), (2.5) and (2.7), and the endogenous output threshold (2.6). 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 equilibrium where agents truthfully report their type. Notice that c^r_{t+1} does not appear in the objective function, since the actual payment of c^r_{t+1} is not an equilibrium. The first order condition can be simplified to

$$\begin{aligned} &\int_{\underline{R}}^{R^*(m)} \left[\frac{p_t}{p_{t+1}} - R_{t+1}\right] U'\Big(\frac{p_t}{p_{t+1}} m_t + R_{t+1}(1-m_t)\Big) f(R)\, dR \\ &+ \int_{R^*(m)}^{\bar{R}} \left[\frac{p_t}{p_{t+1}} U'\Big(\frac{1}{\pi}\frac{p_t}{p_{t+1}} m_t\Big) - R_{t+1}\, U'\Big(\frac{R_{t+1}}{(1-\pi)}(1-m_t)\Big)\right] f(R)\, dR = 0 \end{aligned} \tag{2.10}$$

The first order condition implicitly defines the optimal reserve-deposit ratio, $m_t(p_t/p_{t+1})$.

2.3.5 Equilibrium

A perfect foresight equilibrium of this economy is characterized by the market clearing conditions for real balances[8]. That is, demand for money and supply of money are equal if

$$\frac{M_t}{p_t} = m_t\,(y + \tau_t\,) \tag{2.11}$$

The government budget constraint is $\tau_t = [(\sigma - 1)/\sigma] \quad z_t$. Combining it with (2.11), we have

$$z_t = \frac{m_t\left(p_t/p_{t+1}\right)y}{1 - \left[\left(\sigma - 1/\sigma\right)\right]m_t\left(p_t/p_{t+1}\right)} \tag{2.12}$$

By definition, $\left(p_t/p_{t+1}\right) \equiv \left(z_{t+1}/\sigma z_t\right)$. Substituting this into (2.12), we get

$$z_{t+1} = \sigma z_t\, m_t^{-1}\left(\sigma z_t/(\sigma y + z_t(\sigma - 1))\right). \tag{2.13}$$

This defines the law of motion for the equilibrium stock of real balances.

This environment where banks act as intermediaries will always be preferred to autarky, and agents will choose to deposit their entire endowments in banks[9]. This is because banks provide insurance against the relocation shock, and prevent costly liquidation of investments. In addition, the equilibrium discussed in this section contains no bank runs. This is due to the fact that agents have access to the same information as banks, and thus are willing to accept a contract contingent on this information. In the next section we

[8] Note that since bank portfolio choices occur prior to the realization of R_{t+1}, the equilibrium price level and bank portfolio allocation display no randomness.

[9] See appendix B for a discussion on this.

introduce stronger information asymmetries, so that agents will not find it optimal to accept a contingent contract that they are not able to verify. Given this, preventing bank runs may no longer be optimal.

2.4. 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_{t+1}. Given this, uninformed agents are not able to verify a contract offered by banks that is contingent on the signal on R_{t+1}. 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 contract contingent on R_{t+1} which they can not verify, banks can claim a lower than the true return. In particular, banks could always deceive uninformed movers by claiming a return $\underline{R} = r$, and paying them accordingly. Thus, agents *ex ante* may prefer a contract that is not contingent on R_{t+1}, since if they turn out to be uninformed, they will not be able to verify banks' claims.

Second, we assume that agents are not able to observe when banks' currency reserves are depleted, as in Freeman (1988). However, if banks' resources are entirely exhausted, then they are forced to close, an event observable by depositors. Here again, banks could claim that their currency reserves are depleted, and pay movers 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 may prefer a contract offered by banks that is neither contingent on R_{t+1} 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.

Finally, as in the previous section, banks are not allowed to suspend cash payments nor borrow funds from a monetary authority.

2.4.1 Low Output Runs

When $R_{t+1} > R^*(m)$, agents have the incentive to report truthfully, and the payoffs will be as defined by (2.4) and (2.5). On the other hand, and as in the previous section, when non-movers observe a low return, then they will have the incentive to misreport their type. Banks are aware of this fact, and thus are able to correctly predict the run. However, without being able to verify banks' claims, agents will not accept a contract contingent on R_{t+1}, unless banks liquidate investments and cease to exist. While forced to liquidate, banks can offer the deposit return

$$c_{t+1}^l = \frac{p_t}{p_{t+1}} m_t + r(1 - m_t) \tag{2.14}$$

Lemma 2.4: When banks observe $R_{t+1} < R^*(m)$, they will liquidate according to the deposit return c_{t+1}^l and cease to exist.

Proof: See appendix B.

When both movers and non-movers attempt to withdraw in period one, then banks will exhaust their reserves and be forced to liquidate the investments. Thus, banks face a bank run based on a low realization of output. Figure 2.1 summarizes the expected payoffs to a non relocated agent when the outcome of $R_{t+1} < R^*(m)$. Notice that, as long as $c^m_{t+1} > c_{t+1}$, the game will behave as a prisoner's dilemma, where the unique Nash equilibrium is the one where all non-movers will run. Non-movers will misreport their type, even when the equilibrium payoff is lower than the return where all agents truly report their type.

		Non-Mover	
		Run	Stay
All Other Non-Movers	Run	c^l_{t+1}	0
	Stay	c^m_{t+1}	c_{t+1}

Figure 2.1

2.4.2 Sunspot Panics

When $R_{t+1} > R^*(m)$, no bank 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^r_{t+1} as in the full observation case, since agents will not accept such a contract. Agents can not observe currency 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, unless banks liquidate investments and cease to exist, an event observable by depositors.

Here banks can not observe the variable triggering the run, and thus are not able to predict this type of run. Since they can not foresee the run, they are not able to circumvent the sequential service constraint. Banks will pay out the promised return c_{t+1}^m to agents until they run out of funds. That is, they will only be able to honor the fraction

$$\psi(m) = \pi\left[1 + r\frac{p_{t+1}}{p_t}\frac{(1-m_t)}{m_t}\right] \tag{2.15}$$

Lemma 2.5: When $R_{t+1} > R^*(m)$ *a sunspot run may occur. Banks will then offer the deposit return* c_{t+1}^m *to a fraction* $\psi(m) \in [\pi, 1)$ *of agents and close down.*

The proof follows closely the discussion above and is therefore omitted. Notice that when $\psi(m) = 1$, banks will be able to honor withdrawals from all agents. Then a non-mover that chooses not to run will have goods left in the next period, regardless of what other agents do. Thus, in this case, a sunspot run will be ruled out.

Note that the sunspot variable may be observed when $R_{t+1} < R^*(m)$, but in this case a run will occur with certainty, thus overriding the effect s may have on the lower range of R_{t+1}.

2.4.3 The Bank's Problem

Define ϕ as the probability of a sunspot run occurring when $R_{t+1} > R^*(m)$. Then the bank's problem has the form

$$\begin{aligned} \max \quad & \int_{\underline{R}}^{R^*(m)} U(c_{t+1}^l) f(R)\, dR \;+\; (1-\phi) \int_{R^*(m)}^{\bar{R}} \Big[\pi U(c_{t+1}^m) + (1-\pi) U(c_{t+1})\Big] f(R)\, dR \;+ \\ & +\; \phi \int_{R^*(\gamma)}^{\bar{R}} \psi(\gamma) U(c_{t+1}^m) f(R)\, dR \end{aligned} \tag{2.16}$$

subject to the deposit return schedule given by (2.4), (2.5) and (2.14), the endogenous output threshold (2.6), and the also endogenous fraction (2.15).

The first term represents the fundamental bank run equilibrium due to incentives triggered by a low realization of output, where the sequential service constraint is overcome. The second term represents the equilibrium when there are no runs. Finally, the third term represents the sunspot equilibrium, where the sequential service constraint applies. The first order condition is

$$\begin{aligned} & \left[\frac{p_t}{p_{t+1}} - r\right] U'(c_{t+1}^l) F(R^*) + \; (1-\phi) \int_{R^*(m)}^{\bar{R}} \left[\frac{p_t}{p_{t+1}} U'(c_{t+1}^m) - R_{t+1} U'(c_{t+1})\right] f(R)\, dR \\ & +\; \phi\big[1 - F(R^*)\big]\left[\psi'(m) U(c_t^m) + \frac{1}{\pi}\frac{p_t}{p_{t+1}} \psi(m) U'(c_{t+1}^m)\right] \\ & =\; f(R^*) R^{*\prime}(m) \big[[\phi\psi(m) + (1-\phi)] U(c_{t+1}^m) - U(c_{t+1}^l)\big] \end{aligned} \tag{2.17}$$

2.4.5 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 currency, which is both liquid and non-random, to meet the withdrawing needs of agents. In particular, this involves setting

$$m_t = 1 \tag{2.18}$$

However, in the absence of uncertainty, financial intermediation loses its role in our environment. Under this rule, agents can achieve the same outcome 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.

Proposition 2.1: A contract that eliminates runs through a policy of narrow banking will be worse than the contract with runs for $[F(R^*) + \phi(1 - F(R^*))]\, r + (1-\phi)\int_{R^*}^{\bar{R}} R_{t+1} f(R)\, dR \; > \; p_t/p_{t+1}$.

Proof: When $[F(R^*) + \phi(1 - F(R^*))]\, r + (1-\phi)\int_{R^*}^{\bar{R}} R_{t+1} f(R)\, dR \; > \; p_t/p_{t+1}$ holds, then the expected return on holding risky assets in an environment with runs exceeds the returns on holding money. Therefore, banks will choose to hold positive amounts of the risky asset. Thus, we have $m < 1$. It follows that a contract that specifies $m = 1$ will be suboptimal. ■

Setting $m_t^{\mathrm{nb}} = 1$ is certainly possible for the contract with runs previously discussed. Thus the contract here is a special case of that problem. But we have seen that the optimal share of currency is defined by the first order conditions in (2.17). Further, the optimal share of currency will be less than one for relatively low probabilities of runs.

We can also think of a run preventing contract where banks offer a payment schedule to movers that is low enough so that non-movers will never find it optimal to run. Such a contract would have to satisfy the incentive compatibility constraint $c^m_{t+1} \leq c_{t+1}(R_{t+1})$ for all possible R_{t+1}. *Ex ante*, imposing such a constraint is costly since it forces less risk sharing among depositors[10]. This contract will also be a special case of the contract discussed in the previous section, and thus will not be optimal either.

Completely eliminating runs may not improve welfare relative to a contract with runs. Nonetheless, the contract with runs precludes us from achieving the results from the optimal benchmark environment.

2.5. Lender of Last Resort

In this section we discuss a lender of last resort policy[11]. When a lender of last resort mechanism is implemented, a monetary authority will lend currency to banks in the event of a liquidity shortage. Banks can borrow any quantity they desire in the first period, and must repay the loans to the monetary authority in the following period.

2.5.1 Equilibrium

Define $\hat{M}_t$ is the currency supplied by the discount window, and υ_t as the share of currency borrowed by banks. Then the money market clearing condition for our environment with a lender of last resort will be given by

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[10] the reserve ratio that satisfies this would be $m_t = \dfrac{r}{[(1-\pi)/\pi]\, p_t/p_{t+1} + r}$.

[11] For a thorough discussion of the lender of last resort policy in a similar environment, see Antinolfi, Huybens and Keister (2001).

$$\frac{(M_t + \hat{M}_t)}{p_t} = m_t(y + \tau_t) + \upsilon_t \tag{2.19}$$

where additional currency $\hat{M}_t$ is printed as additional liquidity υ_t is demanded. Thus, we must have

$$\frac{\hat{M}_t}{p_t} = \upsilon_t \tag{2.20}$$

Substituting (2.20) into (2.19) yields the market clearing condition in (2.11). It follows that the market clearing conditions are the same as in the previous sections. The time path of M_t is not affected, since in each period banks repay the amount they borrowed from the discount window in the previous period.

2.5.2 Discount Window

The provision of liquidity allows all agents to withdraw in the first period if they wish to do so. Since banks are allowed to borrow freely, they will do so instead of liquidating the risky asset at a loss. Here, the sunspot equilibrium will be ruled out, since banks will be able to honor agents' demand for deposits by drawing from the discount window and without the need to liquidate assets.

However, fundamental bank runs will not be ruled out. For low realizations of output, non-movers may still have the incentive to run. Nevertheless, banks will be able to draw from the discount window and provide currency to all agents who wish to withdraw early. Movers will carry currency to the other location, while non relocated agents will also hold currency between periods if they choose to withdraw early. At the beginning of the second period, the now old agents will trade their currency for both the m_{t+1} share of endowments of the young and for the matured illiquid investments held by banks. Banks will then be able to repay the loan from the central bank with the currency provided by agents. In this way, costly liquidation is avoided. The currency is then assumed to be destroyed. Notice that this policy is always feasible, since it requires no real resources from the central bank.

If we define η_{t+1} as the discount window rate charged by the central bank, then the bank's constraints become

$$c_{t+1}^{m} = \frac{1}{\pi}\frac{p_t}{p_{t+1}}(m_t + \upsilon_t) \tag{2.21}$$

$$c_{t+1}(R_{t+1}) = \frac{1}{(1-\pi)}[R_{t+1}(1-m_t) - \eta_{t+1}\upsilon_t] \tag{2.22}$$

When $R_{t+1} > R^*(m)$, then $\upsilon_t = 0$, since the announcement of the policy will suffice to rule out sunspots, and we should not observe them in equilibrium. Notice that when $\upsilon_t = 0$, (2.21) and (2.22) simply become (2.4) and (2.5), respectively.

Now introducing central bank borrowing allows us to collapse the constraints (2.21) and (2.22) into

$$\pi c_{t+1}^{m} + (1-\pi)c_{t+1}(R_{t+1}) = \frac{p_t}{p_{t+1}}m_t + R_{t+1}(1-m_t) + \left[\frac{p_t}{p_{t+1}} - \eta_{t+1}\right]\upsilon_t \tag{2.23}$$

Recall that when $R_{t+1} < R^*(m)$, all agents pretend to be movers and banks are not able to distinguish them. It follows that banks will be forced to offer everybody the same consumption. Hence c_{t+1}^{m} and $c_{t+1}(R_{t+1})$ will necessarily be equal. Then we can rewrite (2.23) as

$$c_{t+1}^{d}(R_{t+1}) = \frac{p_t}{p_{t+1}}m_t + R_{t+1}(1-m_t) + \left[\frac{p_t}{p_{t+1}} - \eta_{t+1}\right]\upsilon_t \tag{2.24}$$

If the monetary authority follows a policy of setting the discount rate $\eta_{t+1} = p_t/p_{t+1}$, then the last term of the resource constraint in (2.24) drops out. That is, such a policy will make $c_{t+1}^{d}(R_{t+1})$ equal to $c_{t+1}^{c}(R_{t+1})$, the return schedule given by (2.7). Consequently, the bank's problem in an environment with information asymmetries and a lender of last resort policy will be equal to the problem in the full observation environment where banks could offer a contingent contract. Therefore banks under a lender of last resort mechanism that sets the discount rate equal to the inverse of the inflation rate, gives the bank's problem in (2.9), subject to the deposit return schedule given by (2.4), (2.5) and (2.7), and the output threshold (2.6). Accordingly, the first order condition will be given by (2.10).

Proposition 2.2: When a monetary authority acts as a lender of last resort, the optimal contract offered by banks will accomplish the full observation optimum. This can be achieved by the central bank setting the discount window rate equal to the inverse of the inflation rate, and by making public when the discount window is drawn on.

Notice that under this scenario, if the monetary authority makes public whenever the discount window is used, then movers can use that information to infer in which state of the world they are. That is, if the central bank announces that the discount window is being drawn on, they infer that they are in a state of the world where output is low, and thus are willing to accept a payment contingent on R_{t+1}. If, instead the central bank does not announce that the discount window is being drawn on, then they conclude that $R_{t+1} > R^*(m)$, and they only accept a payment of c^m_{t+1}. Agents will not accept a contract where banks set m_t=0 and borrow from the discount window to provide liquidity. In this case, $R^*(m)$=0, and non-movers will not run. Then banks could claim $\underline{R}$

and pay movers accordingly. It follows that agents will not accept a contract where banks choose a reserve ratio less than the one in the benchmark model.

Further notice that here the central bank has no need for information on R_{t+1}. All it needs to do is follow a simple rule. In the first period, the central bank readily prints money on demand, and announces publicly when it does so. In the second period, after prices are realized, it simply matches its discount rate to the inverse of the inflation rate.

The central bank has thus two roles: it provides liquidity when banks need it, and it allows movers to infer the state of the economy. Notice however, that these roles need not necessarily be carried by a government institution. A private institution that is given the right to issue notes and announce it publicly can achieve the same outcome[12].

The contract under this monetary policy turns out to be the same contract as the one specified under full observation. What changes is the underlying story behind the outcomes. In the full observation problem, it was all agents observing both the signal on R_{t+1} and banks' depletion of reserves. Since agents were able to verify bank claims, they accepted a contingent contract. Under a lender of last resort mechanism, this optimal contingent contract can be achieved via the introduction of an elastic supply of money.

[12] In Champ, Smith and Williamson (1996), banks themselves are allowed to issue notes to accommodate withdrawals. Here, the fact that agents do not trust banks precludes this.

2.6. SUSPENSION OF CONVERTIBILITY

In this section, we analyze a regime that allows suspension of convertibility. Under this policy, banks in the first period will honor withdrawals from the first π share of consumers, after which they will suspend payments until the following period. Banks will offer these first π consumers the fixed gross real return c^m_{t+1}. In the following period, banks will offer the return c_{t+1} to the remaining (1-π) 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 with high realizations of output.

On the other hand, when $R_{t+1} < R^*(m)$, non-moving 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 agent who learns that it will be relocated faces the probability (1-π) of being late in line when it reports to the bank. These agents who arrive late in line will in fact be relocated without having received a payoff from the bank, and their consumption will be zero.

In contrast, non-movers who misreport their type face the probability π of receiving c^m_{t+1}. However, with probability (1-π) they arrive late. Since they are not relocated they simply wait until the following period to withdraw c_{t+1}. Given this, the problem of the bank can be shown to be of the form

$$\max\ \pi U(c_{t+1}^m) - \int_{\underline{R}}^{R^*(m)} \pi(1-\pi)U(c_{t+1})f(R)\,dR \ + \int_{R^*(m)}^{\bar{R}} (1-\pi)U(c_{t+1})f(R)\,dR \qquad (2.25)$$

subject to the deposit returns (2.4) and (2.5), and the threshold (2.6). The first order condition is

$$\begin{aligned}&\frac{p_t}{p_{t+1}}U'(c_{t+1}^m) + \int_{\underline{R}}^{\bar{R}} R_{t+1}\,U'(c_{t+1})f(R)\,dR \\ &= \pi(1-\pi)\int_{\underline{R}}^{R^*(m)} U'(c_{t+1})f(R)\,dR \ + \ \pi(1-\pi)U(c_{t+1})f(R^*)R^{*\prime}(m)\end{aligned} \qquad (2.26)$$

Consider a numerical example. Assume $U(c_{t+1}) = c^{1-\rho}/(1-\rho)$ with $\rho = 0.5$, and F(R) to be a uniform distribution. Further, assume $M = 0.44$, $\pi = 0.5$, $\bar{R} = 3$, $\underline{R} = r = 0.1$. If we let V^{sc} be the indirect utility function under suspension of convertibility, then $V^{sc} = 2.14$, while under full observation, $V^{o} = 2.2$. Accordingly, expected utility for suspension of convertibility does not attain the full observation optimum. Further, for our particular example, suspension of convertibility will reduce welfare relative to the equilibrium with bank runs. Here, $V^{sc} = 2.14$ while the contract banks can offer when no such policy is in place attains $V^{b} = 2.15$. 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 c_{t+1}^{l}.

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.

2.7. CONCLUSION

We studied an environment where both sunspots and fundamental bank runs may take place, and where spatial separation and limited communication generate a transaction role for money. When the environment contains bank runs, banks are forced to liquidate the long term investments. This outcome has room for improvement, especially if compared to a full observation environment where costly asset liquidation is prevented.

We then looked at 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 will not be an optimal policy.

We find that a policy of suspension of convertibility, while preventing costly liquidation, may still not reach the optimal outcome. Further, suspension of convertibility may reduce welfare relative to a contract with runs, if the probability of sunspot runs is low enough.

In contrast, a policy where a monetary authority lends currency to banks in the event of a liquidity shortage may achieve the optimal outcome. A central bank will attain this by charging an interest rate on the discount window equal to the inverse of the inflation rate. As a result, this injection of money will not be inflationary. Under this policy, and similar to suspension of convertibility, sunspot runs will be prevented while fundamental runs will still occur. This monetary policy will realize the optimal outcome by preventing speculative runs while optimally distributing risk in the unavoidable runs. When a fundamental run takes place, the elastic supply of money will accommodate agents' demand for liquidity, and consequently payoffs will be optimally adjusted without the need of costly liquidation.

Chapter 3

All Banking Crises Are Not Created Equal

3.1 Introduction

The last 25 years have seen the resurgence of banking crises, with some prominent examples occurring in Latin America and Asia. When banks fail, the consequences are felt across the entire economy, with some dramatic examples[13]. There are two main theoretical 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)[14]. 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 the deterioration of macroeconomic variables. Examples of these are the original Diamond and Dybvig (1983), Freeman (1988), Cooper and Ross (1997), and Peck and Shell (2002).

While one literature views the banking crisis as a consequence of poor macroeconomic performance, the other views it as the actual cause of macroeconomic downturns. For example, Argentina seems to be an economy

[13] See Caprio and Klingebiel (2003) for some figures.

[14] Champ Smith and Williamson (1996) and Smith (2002) are also considered part of the fundamentals literature. However, they differ in that their crises are caused mainly by aggregate uncertainty in liquidity preference, rather than poor economic performance.

where both self-fulfilling and fundamental crises may have occurred within a seven year period. Its first crisis, known as the "tequila" crisis, was triggered by the December 20, 1994 devaluation of the Mexican peso. The Mexican devaluation had no fundamental effect on Argentina, since both countries have a very limited relationship. Further, Argentina was coming from a four-year expansion, where GDP growth for the 1991-94 period averaged 8.2%. It therefore seems that the tequila crisis is best explained by the self-fulfilling literature. In contrast, the current crisis that started in 2001 appears to be caused by poor macroeconomic performance. In the four years preceding the crisis, the economy was immersed in a deep recession. In November 2001, as banks were at the verge of collapsing, the government suspended the withdrawal right of depositors. Consequently, it appears to be that the current crisis best fits the fundamentals explanation. It therefore appears that both types of crises are not mutually exclusive, but each may best represent distinct states of the world.

The goal of this paper is to investigate the factors that may be associated with self-fulfilling and fundamental banking crises. Identifying these characteristics is important since policy implications may be different depending on the type of crises an economy faces[15]. If banking crises are due to fundamentals, then macroeconomic stabilization policies should be critical to prevent such occurrences. Further, once a crisis is underway, suspension of convertibility may be more harmful than beneficial if the crisis is based on fundamentals. On the other hand, if a crisis is due to multiple equilibria, then

[15] On this see Fontenla (2003), where I model both types of runs in a demand-deposit environment in order to examine its policy implications.

policies conductive to eliminate indeterminacies and volatility may be the adequate government measure.

The empirical literature on the causes of banking crises has grown large in the last few years as a consequence of the resurgence and significance of these crises[16]. Empirical work that addresses the divergence in the theoretical literature has been mixed. 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 (1998a) confirm Gorton's findings for a sample of countries for the 1980-94 period. Using a binomial logit model, they find that the risk of banking crises is heightened mainly by slow growth, high inflation and high real interest rates. In contrast, 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. They conclude that banking crises may often be the outcome of bad realizations of sunspot equilibria.

In this paper, we construct an index that differentiates between the two types of banking crises. This allows us to use a multinomial logit model to investigate the determinants of self-fulfilling and fundamental banking crises. By doing this, important characteristics particular to each type of run come to light which are not accounted for by standard binomial logit specifications. We find

[16] See Eichengreen and Arteta (2002) for an excellent summary of the literature.

evidence indicating that the two types of crises are indeed different, and are explained by different variables.

Self-fulfilling crises tend to occur when bank liabilities relative to reserves are high, for periods of rapid domestic credit growth and when the financial system is liberalized. In addition, self-fulfilling crises are associated with government surpluses and high levels of short-term debt relative to total debt. In contrast, fundamental crises are linked to depreciations of the local currency, to financial liberalization and to the country's level of development as proxied by GNP per capita. Also, countries that experienced multiple crises are more likely to experience fundamental crises.

Finally, by accounting for the possibility of self-fulfilling crises, our results provide better support to existing self-fulfilling theoretical models. In particular, our results agree with the self-fulfilling banking models outlined above, and more generally to financial crises models such as Calvo and Mendoza (1996), and Cole and Kehoe (2000).

3.2 Data

The data covers the period 1974-1997 for 51 developing countries. Following previous literature, we exclude centrally planned economies and high income OECD countries[17]. The identification and dating of banking crises is taken from Caprio and Klingebiel (2003). Caprio and Klingebiel divide crises between systemic, defined as much or all capital being exhausted, and smaller,

[17] Here I follow Eichengreen and Arteta in keeping Mexico and Korea in the sample, both OECD countries, since we can consider them to be developing countries.

borderline events. There are 84 systemic banking crises in our period. Since crises often last several years, we consider only the first observation for each systemic banking crisis, in order to prevent reverse causality.

3.3 IDENTIFYING TYPES OF CRISES

Fundamental banking crises, as their name suggests, are driven by adverse changes in macroeconomic fundamentals. In particular theory suggests that negative or weak GDP growth, excessively high real interest rates and high inflation should all be causes of fundamental banking crises[18]. Adverse output growth deteriorates the returns of bank investments, and this may trigger banking crises. High short-term interest rates may produce a mismatch between rates of return on assets and liabilities, since banks liabilities tend to be short-term while bank assets usually have longer maturities. Finally, high inflation rates may affect real returns and exacerbate financial market frictions (Barnes, Boyd and Smith, 1999; Boyd, Levine and Smith, 2001).

Given this, we use a simple method to identify types of crises, following similar work by Eichengreen, Rose and Wyplosz (1996) and Kaminsky and Reinhart (1999)[19]. We construct a weighted average of lagged GDP growth, real interest rates and inflation, for the systemic crises identified by Caprio and

[18] Demirgüç-Kunt and Detragiache (1998a) find these three variables to be determinants of banking crises, which leads them to favor the idea that crises are best explained by the fundamentals literature.

[19] Eichengreen et al create an index of exchange rate speculative pressure by creating a weighted average of exchange rate changes, reserves and interest rate changes. Kaminsky and Reinhart create a similar index based on exchange rate and reserves changes.

Klingebiel. The three components of the index are weighted so that their conditional volatilities are equal. Then, when this index falls below a threshold, we identify it as a fundamental crisis. Conversely, when GDP growth is high, and interest rates and inflation are low, we label it a self-fulfilling crisis[20].

Table 1 ranks the 50 crises we are able to measure according to this classification criteria, and shows the values for the three lagged variables included in the index. Roughly, we set the threshold such that it will label a crisis self-fulfilling when GDP growth exceeds 4 percent, and real interest rates and inflation are reasonable. Notice from table 1 that the 1995 Tequila and the 1997 Asian crisis all fall in the self-fulfilling group, which explains the resurgence of theoretical models of self-fulfilling crises. Finally, given the ad-hoc, but hopefully intuitive, nature of this threshold, we conduct sensitivity analysis to see how lowering or raising this threshold matters. We find the main conclusions to be robust.

3.4 EXPLANATORY VARIABLES

Explanatory variables are chosen to reflect both theory and previous empirical work, subject to data availability. We choose to lag all of the variables by one period in order to rule out reverse causality. For example, if we were to use a contemporaneous measure of depreciation, we may find that depreciation is correlated with banking crises. We then may erroneously conclude that

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[20] It seems impossible to directly identify self-fulfilling crises, since they are based on agents' beliefs, which are hard to measure. However, at a very minimum, these crises are not the consequence of deterioration of these fundamental macroeconomic variables.

depreciation explains crises when truly large depreciations may be government responses or consequences of banking crises.

All regressions include the rate of depreciation, a ratio of M2 to foreign exchange reserves, a measure of domestic credit growth, a financial liberalization dummy, government surplus to GDP, a ratio of short-term to total debt, and GNP per capita. We also add a dummy for multiple crisis countries, dummies for fixed and floating exchange rates, a measure terms of trade changes, northern interest rates and OECD growth.

We include the rate of depreciation of the exchange rate relative to the US dollar. This intends to capture the extent to which sharp depreciations may cause crises in countries over exposed to foreign exchange risk. In good times, domestic banks in developing countries often borrow abroad in foreign currency, and lend domestically in the local currency. However, when the wind shifts, depreciations then produce a mismatch between rates of return on assets and liabilities.

To measure vulnerability to capital outflows, we include the ratio of M2 to foreign exchange reserves. M2 may be thought as a proxy for liabilities of the banking system. When M2 exceeds foreign reserves, a negative money demand shock, perhaps self-fulfilling, may render fixed exchange rates implausible (Calvo and Mendoza, 1996). Domestic Credit Growth is used to account for the view that bank lending booms generally precede crises. Lending booms can foster vulnerability by causing a decline in the quality of bank's assets (Gavin and Hausmann, 1998).

We incorporate a financial liberalization dummy, since lifting restrictions on capital flows may increase its volatility and allow for foreign exchange risk.

Also, financial liberalization of the banking system may increase competition, thus reducing profit opportunities. Further, lifting restrictions on banks may allow them to take on riskier projects. Especially in the early years of liberalization, bank managers may not have the skills required to screen and monitor risky portfolios. Because of these reasons, banks may become more vulnerable when financial systems are liberalized. Previous empirical work finds that financial liberalization significantly increases the probability of banking crises.

Government surplus as a percentage of GDP signals the ability of governments to repay their debts. Banks in developing countries often hold large shares of their portfolios in government debt, rendering them vulnerable to government's capacity to repay. We also include a ratio of short-term to total external debt. Cole and Kehoe (2000) construct a model where if government debt and its maturity structure reach a critical level, they generate fear of default on part of international bankers which becomes self-fulfilling. Rodrik and Velasco (1999) develop a theoretical model linking short-term debt to crises, and find empirical evidence that short-term debt to reserves ratio is a robust predictor of financial crises.

GNP per capita is added as a control variable, since it may be thought as a proxy for the development of the financial system, quality of institutions and quality of data, as all these variables are thought to be positively correlated with GNP per capita.

We add a dummy variable for countries that experienced multiple crises, since Boyd et al (2001) find that what determines a crisis is different across countries that experience only one crisis in the last 25 years versus those that have had repeated crises.

Fixed exchange rates have often been linked to banking crises, because they may induce banks to excessively borrow abroad. This increases banks' vulnerability in that if fixed exchange rates are abandoned, banks liabilities increase in proportion to devaluations. Floating exchange rates, on the other hand, may be viewed as generating exchange risk and adding another layer of uncertainty to banks. Following Eichengreen and Arteta (2002), we include dummies for both fixed and floating exchange rates.

To measure real external effects, we include a measures of northern interest rates and OECD growth. Changes in capital flows respond to changes in world interest rates and world output growth. Finally, to account for external shocks in trade that may cause financial distress, we also add a variable measuring terms of trade changes.

3.5 RESULTS

We begin the analysis by using a binomial logit model where the independent variable is the Caprio and Klingebiel crisis dates, for the purpose of comparing it to previous work and to our multinomial logit regressions. Table 2 reports the regressions for the variables described above. P-values are reported in parenthesis, where they denote the probability that the coefficient is equal to zero.

The ratio of M2 to foreign exchange reserves, financial liberalization and domestic credit growth all are significant across specifications, agreeing with previous work, in particular Demirgüç-Kunt and Detragiache (1998b) and Eichengreen and Arteta (2002). The rate of depreciation becomes significant at the 10 percent level when we control for exchange rate regimes, but loses significance in all other regressions.

The dummy representing countries that experienced multiple banking crises enters significantly at the 5 percent level, agreeing with Boyd et al (2001). As in Eichengreen and Rose (1998), northern interest rates are associated with banking crises in this specification. Short-term to total debt enters significantly at the 10 percent level for some specifications, but does not appear to be robust. Finally, the other variables considered have no significant effect in this model.

We then divide crises into self-fulfilling and fundamental according to our index, and run maximum-likelihood multinomial logit regressions. Table 3 presents the main results of this paper. The first specification in table 3 provides the benchmark regression, the second regression includes the dummy for countries that experienced multiple crises, and the third specification tests different exchange rate regimes. To test for external factors that may cause banking crises, regression 4 includes changes in the terms of trade and regression 5 includes both northern interest rates and OECD growth rates. The quality of the model specification is tested by the model χ^2, where the hypothesis that the coefficients of the independent variables are jointly equal to zero is tested. We reject the hypothesis at the 1 percent level in all regressions.

Further, and more interestingly, we test that all the coefficients except the constant are equal across the self-fulfilling and fundamental equations. We report the p-values at the bottom of each specification. In the baseline regression the hypothesis that self-fulfilling and fundamental crises are equal is rejected at the 1 percent significance level. For all other specifications we reject it at least at the 5 percent level. This leads us to believe that all banking crises are not alike, and perhaps both self-fulfilling and fundamental theories are correct.

In all regressions, the coefficient for the rate of depreciation is negative (appreciation) but not significant for self-fulfilling crises. In contrast, the rate of depreciation is positively associated with a higher probability of fundamental crises. The coefficient is significant at the 5 percent level for all specifications. Notice that for the binomial logit regressions in table 2, depreciation shows no significant effect for most regressions. In this sense, by differentiating between the two types of crises, we are disentangling important characteristics particular to each type of run.

The ratio of M2 to gross international reserves is positive and highly significant for all self-fulfilling crises, but loses significance for fundamental crises. While the significance of this variable is also picked up in the binomial regressions, the results given by accounting for both types of crises provides stronger support to self-fulfilling theoretical models such as Calvo and Mendoza (1996).

The rate of domestic credit growth tells a similar story, in that it is positively associated with self-fulfilling banking crises while it shows no effect for fundamental crises. This confirms the idea that lending booms may have played an important role in self-fulfilling events.

The financial liberalization dummy is strongly significant in the binomial logit specification, and continues to be significant across both types of crises when we run multinomial logit regressions. This suggests that financial liberalization may be conducive to the existence of indeterminacies and excess volatility, and may also have direct effects on bank's balance sheets through increased competition and risk taking.

Government budget surplus as a percent of GDP is positive and significant at the 5 percent confidence level for all self-fulfilling crises, except when the multiple crises dummy is introduced. For fundamental crises the coefficient is not significant, but negative. This result sheds light over previous empirical work that is not able to explain their finding that budget surpluses, rather than deficits, are associated with banking crises. Our interpretation here is that budget surpluses support the notion that it is not fundamentals that are causing these group of crises. In contrast, for the group of fundamental crises, the intuitive negative sign denoting deficits is found.

Short term debt to total debt is positive and significant at the 5 percent level for all self-fulfilling crises, and negative and insignificant for fundamental crises. This result provides strong support for Cole and Kehoe's theoretical model of self-fulfilling debt crises.

We find support for the belief that less developed countries, or countries with weaker institutions, are more prone to fundamental crises, as proxied by GNP per capita. This variable is negative and significant at the 10 percent level for fundamental crises except when terms of trade changes are introduced, and shows no effect for self-fulfilling crises. When we introduce the multiple crises dummy, we find backing for the idea that countries that experienced multiple banking crises are more vulnerable to fundamental crises.

All other variables introduced in our regressions show no significant effect on either type of crises. Northern interest rates show no effect on either equation, when its coefficient was significant for the binomial logit regression.

3.6 CONCLUSION

This paper applied a very simple method to differentiate between fundamental and self-fulfilling crises. We then run multinomial logit regressions, and find strong evidence indicating that the two types of crises are indeed different, and are explained by different variables. The assessment of economic conditions that lead to these types of crises becomes essential, since policy implications may be different depending on the type of crises an economy faces.

Self-fulfilling crises tend to occur when M2 relative to reserves is high, for periods of rapid domestic credit growth and when the financial system is liberalized. In addition, self-fulfilling crises are associated with government surpluses and high levels of short-term debt relative to total debt, results that are not present in the binomial logit model. In contrast, fundamental crises are linked to depreciations of the local currency, to financial liberalization and to the country's level of development as proxied by GNP per capita. Also, countries that experienced multiple crises are more likely to experience fundamental crises.

By accounting for the possibility of self-fulfilling crises, our results provide better support to self-fulfilling theoretical models. In particular, our results agree with models such as Diamond and Dybvig (1983), Calvo and Mendoza (1996), and Cole and Kehoe (2000).

Table 1

Banking Crises: Index

Country	CrisisYear	GDP growth	Real Interest	Inflation	Index
Bolivia	1986	-1.68	-97.81	11749.61	-9.06125
Brazil	1990	3.28	4974.25	1430.73	-7.949196
Chad	1980	-21.44	0.29	8.19	-4.004833
Brazil	1994	4.90	1356.46	1927.98	-2.546432
Burundi	1994	-5.71	2.52	9.68	-1.075489
Argentina	1989	-1.89	180.73	342.95	-0.8772328
Ghana	1982	-3.50	-32.25	116.50	-0.7872517
Togo	1993	-3.98	13.81	1.39	-0.7642791
Zambia	1995	-3.43	8.94	53.61	-0.6928381
Panama	1988	-1.81	10.08	1.00	-0.3533107
Benin	1988	-1.50	10.16	3.03	-0.2972938
Burkina Faso	1988	-1.35	11.68	-2.68	-0.2719275
Cote d'Ivoire	1988	-0.35	18.32	6.94	-0.0978344
Venezuela	1994	0.25	13.07	38.12	-0.0007555
Jamaica	1994	1.43	6.95	22.07	0.2406257
Kenya	1992	1.44	6.68	19.82	0.2436258
Niger	1983	1.62	4.89	11.64	0.286781
Nepal	1988	1.70	2.06	10.75	0.3052191
Kenya	1985	1.76	3.91	10.28	0.3138735
El Salvador	1989	1.88	0.65	19.76	0.3346719
Ecuador	1996	2.34	26.33	22.89	0.3804255
Congo, Rep.	1992	2.40	19.94	9.16	0.4107605
Sri Lanka	1989	2.47	2.09	13.99	0.4477193
Paraguay	1995	3.09	9.46	20.57	0.5463623
Guinea-Bissau	1995	3.20	10.62	15.18	0.57037

Notes: GDP growth, real interest rates and inflation are lagged one year. Where the index is given by $I = GDPG/\sigma_{GDPG} - |RIR/\sigma_{RIR}| - |INF/\sigma_{INF}|$

Table 1 cont'd

Banking Crises: Index

Country	CrisisYear	GDP growth	Real Interest	Inflation	Index
Cape Verde	1993	3.26	6.37	3.12	0.596069
Swaziland	1995	3.46	1.77	14.31	0.6314512
Mauritania	1984	3.74	4.42	7.26	0.6845862
Ecuador	1982	3.94	-4.68	16.39	0.7162723
Bolivia	1994	4.27	44.41	8.53	0.7228766
Senegal	1988	4.00	11.30	-4.14	0.7263432
Guinea	1993	4.27	1.59	25.01	0.7762778
Bangladesh	1987	4.34	3.82	11.04	0.7954443
Mexico	1995	4.42	11.18	6.97	0.8013953
Sierra Leone	1990	4.95	-19.46	60.80	0.8495151
Philippines	1981	5.15	-0.22	18.20	0.9464962
Thailand	1983	5.35	11.33	5.26	0.977164
Thailand	1997	5.52	9.00	5.81	1.011295
Costa Rica	1987	5.53	3.17	11.84	1.018159
Uruguay	1981	5.84	7.66	63.48	1.031581
Cameroon	1987	6.77	13.29	7.77	1.237033
Zimbabwe	1995	6.84	8.99	22.26	1.246215
Korea, Rep.	1997	7.06	5.22	4.92	1.305834
Indonesia	1997	7.82	9.71	7.97	1.438696
Chile	1981	8.15	14.27	35.14	1.4723
Argentina	1995	8.01	8.71	4.18	1.476774
Nigeria	1991	8.20	16.93	7.36	1.497466
Mali	1987	8.44	15.09	-1.38	1.549582
Malaysia	1997	8.58	3.53	3.49	1.591595
Vietnam	1997	9.34	16.72	6.14	1.712162

Notes: GDP growth, real interest rates and inflation are lagged one year. Where the index is given by $I = GDPG/\sigma_{GDPG} - |RIR/\sigma_{RIR}| - |INF/\sigma_{INF}|$

Table 2

Banking Crises: Binomial Logit Regressions

	(1)	(2)	(3)	(4)	(5)
Variables					
Depreciation	0.17693	0.1168806	0.1816134	0.1570966	0.1705798
	(0.104)	(0.268)	(0.098)	(0.144)	(0.106)
M2 / Gross Int'l Reserves	0.0436406	0.0382265	0.0428331	0.0457394	0.0537812
	(0.052)	(0.095)	(0.056)	(0.044)	(0.018)
Domestic Credit Growth	0.0058132	0.0051465	0.0058602	0.0055762	0.0057089
	(0.009)	(0.027)	(0.010)	(0.016)	(0.015)
Financial Liberalization	1.716014	1.703842	1.723896	1.634726	1.881389
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)
Gov't Budget Surplus / GDP	0.0509828	0.0222437	0.0504099	0.0287788	0.0703162
	(0.254)	(0.613)	(0.257)	(0.570)	(0.119)
Short Term Debt / Total	0.029232	0.0310086	0.0298204	0.0323952	0.0226192
	(0.102)	(0.082)	(0.098)	(0.080)	(0.239)
GNP per Capita	-0.000059	-0.0000674	-0.0000696	-0.00005	-0.0000498
	(0.593)	(0.535)	(0.544)	(0.652)	(0.672)
Multiple Crises	--	0.9189972	--	--	--
	--	(0.031)	--	--	--
Fixed Exch. Rate	--	--	-0.0540256	--	--
	--	--	(0.912)	--	--
Floating Exch. Rate	--	--	-0.1686768	--	--
	--	--	(0.747)	--	--
Terms of Trade Change	--	--	--	-0.8404238	--
	--	--	--	(0.616)	--
Northern Interest Rate	--	--	--	--	0.0099069
	--	--	--	--	(0.020)
Northern Output Growth	--	--	--	--	-18.96226
	--	--	--	--	(0.238)
Observations	657	657	653	621	657
LR chi2	42.25	46.68	42.12	40.15	49.88
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000
Pseudo R2	0.1614	0.1784	0.1612	0.1593	0.1906

Notes: Multivariate Logit. P-values are given in parenthesis.

Table 3

Banking Crises: Multinomial Logit

	(1)		(2)		(3)	
	Self-Fulfilling	Fundamental	Self-Fulfilling	Fundamental	Self-Fulfilling	Fundamental
Variables						
Depreciation	-1.073958	0.4830678	-1.120047	0.394626	-1.146996	0.5136561
	(0.330)	(0.013)	(0.299)	(0.034)	(0.282)	(0.011)
M2 / Gross Int'l Reserves	0.0926691	0.0122651	0.0919857	0.0077246	0.0977948	0.0109191
	(0.003)	(0.747)	(0.003)	(0.840)	(0.003)	(0.771)
Domestic Credit Growth	0.0096085	0.0017656	0.0088151	0.0014686	0.009587	0.0017895
	(0.014)	(0.628)	(0.031)	(0.700)	(0.019)	(0.625)
Financial Liberalization	1.678321	1.416992	1.549311	1.359341	1.467098	1.624925
	(0.053)	(0.034)	(0.077)	(0.044)	(0.091)	(0.021)
Gov't Surplus / GDP	0.2319527	-0.0135162	0.1841148	-0.0356503	0.268821	-0.0129637
	(0.037)	(0.800)	(0.111)	(0.470)	(0.026)	(0.818)
Short Term Debt / Total	0.0557317	-0.0276998	0.0567809	-0.0306277	0.0611751	-0.0212404
	(0.034)	(0.501)	(0.028)	(0.472)	(0.030)	(0.589)
GNP per Capita	0.0000587	-0.0006295	0.0000812	-0.0006379	0.0000911	-0.0006398
	(0.673)	(0.088)	(0.559)	(0.077)	(0.570)	(0.087)
Multiple Crises	--	--	0.6748266	1.159765	--	--
	--	--	(0.355)	(0.096)	--	--
Fixed Exch. Rate	--	--	--	--	0.0245935	0.5116356
	--	--	--	--	(0.978)	(0.578)
Floating Exch. Rate	--	--	--	--	0.9928716	-0.1590694
	--	--	--	--	(0.270)	(0.873)
Observations		650		650		646
LR chi2		60.26		63.58		62.64
Prob > chi2		0.0000		0.0000		0.0000
Pseudo R2		0.2369		0.25		0.2466
Test Sunspots=Fundamentals						
chi2		18.79		18.82		19.72
Prob > chi2		0.0089		0.0158		0.0197

Notes: Multinomial logit. P-values are given in parenthesis.

Table 3 cont'd

Banking Crises: Multinomial Logit

	(4)		(5)	
	Self-Fulfilling	Fundamental	Self-Fulfilling	Fundamental
Variables				
Depreciation	-1.111658	0.4448102	-1.147478	0.487923
	(0.330)	(0.020)	(0.308)	(0.013)
M2 / Gross Int'l Reserves	0.0906095	0.017889	0.1008191	0.0135123
	(0.003)	(0.640)	(0.002)	(0.725)
Domestic Credit Growth	0.009806	0.0015683	0.0095749	0.0016632
	(0.013)	(0.669)	(0.014)	(0.658)
Financial Liberalization	1.615514	1.438828	1.848188	1.42472
	(0.062)	(0.031)	(0.038)	(0.038)
Gov't Budget Surplus / GDP	0.2258436	-0.0286585	0.2458352	-0.0088075
	(0.045)	(0.625)	(0.025)	(0.867)
Short Term Debt / Total	0.0567259	-0.0272917	0.0491883	-0.0283277
	(0.035)	(0.508)	(0.072)	(0.502)
GNP per Capita	0.0000526	-0.0005785	0.0000792	-0.0006336
	(0.707)	(0.110)	(0.587)	(0.091)
Terms of Trade Change	-0.6571291	-0.9176985	--	--
	(0.836)	(0.715)	--	--
Northern Interest Rate	--	--	0.0080832	0.0022815
	--	--	(0.222)	(0.772)
Northern Output Growth	--	--	-10.48022	-14.27874
	--	--	(0.709)	(0.545)
Observations		615		650
LR chi2		59.28		62.44
Prob > chi2		0.0000		0.0000
Pseudo R2		0.2358		0.2455
Test Sunspots=Fundamentals				
chi2		18.55		19.38
Prob > chi2		0.0175		0.0222

Notes: Multinomial logit. P-values are given in parenthesis.

Appendices

Appendix A

Proof of Lemma 1.1

Suppose the opposite, that is, that foreign patient agents choose to deposit in a domestic bank. Then $\phi_2^f = N_2^f$, and by (1.17), $c_2 > R$. It follows that $c_1 < 1$ by the feasibility constraints. This implies that $\phi_1^f = 0$ by (1.15). The first order condition to this problem sets $m = \frac{1}{1+\left(\frac{(1-N_1^d)}{N_1^d}\right)^{1/\rho}\left(\frac{(1-\lambda)}{\lambda}\right)^{(\rho-1)/\rho}R^{(1-\rho)/\rho}}$ where $\lambda = \frac{\phi^d \pi^d}{\phi^d + \phi_2^f} < N_1^d$.

$c_1 < 1$ further implies $m < \lambda$ by (1.11). Thus we have

$$\frac{1}{1+\left(\frac{(1-N_1^d)}{N_1^d}\right)^{1/\rho}\left(\frac{(1-\lambda)}{\lambda}\right)^{(\rho-1)/\rho}R^{(1-\rho)/\rho}} < \lambda \tag{A.1}$$

after some algebra and taking the natural logarithm to the above expression, we have

$$\ln\left(\frac{(1-N_1^d)}{(1-\lambda)}\frac{N_1^d}{\lambda}\right) < (1-\rho)\ln(R) \tag{A.2}$$

Which is a contradiction for $\rho>1$, since both expressions inside the logarithms are greater than one. ■

Proof of Proposition 1.1

It is easy to verify that the optimal reserve ratios that solve (1.10) for the pooling and separating outcomes are m^p and m^s given by (1.20) and (1.21), respectively.

Consider first the pooling case. Then $\lambda = \frac{N_1^d + N_1^f}{N_1^d + N_2^d + N_1^f}$. Further suppose that that N_1^f is small enough so that λ is arbitrarily close to N_1^d. It follows that m^p is arbitrarily close to the benchmark m^d given by (1.7) and is thus preferred to m^s. Then, by continuity, the threshold $\hat{N}_1^f$ given by (1.22) exists and satisfies $m^p = m^s$, such that $\phi_1^f = N_1^f$ for $N_1^f \leq \hat{N}_1^f$ and $\phi_1^f = 0$ for $N_1^f > \hat{N}_1^f$. ■

Proof of Proposition 1.2

The optimal fraction of currency banks liquidate, α, needs to satisfy

$$\tfrac{(1-\alpha)}{(1-\lambda)} m + \tfrac{(1-\delta)}{(1-\lambda)} R(1-m) \geq \tfrac{\alpha}{\lambda} m + \tfrac{\delta}{\lambda} r(1-m) \tag{A.3}$$

with strict equality for α<1. Then the threshold $\underline{N}_1$ follows from setting α=1 with strict equality of (A.3), and δ=0. Then we have the optimal currency liquidation strategy

$$\alpha = \begin{cases} N_1(1 + R\frac{(1-m)}{m}) & \text{for } N_1 \leq \underline{N}_1 \\ 1 & \text{for } N_1 > \underline{N}_1 \end{cases} \tag{A.4}$$

Similarly, the optimal fraction of investments liquidated, δ, satisfies

$$\tfrac{(1-\alpha)}{(1-\lambda)} m + \tfrac{(1-\delta)}{(1-\lambda)} R(1-m) \leq \tfrac{R}{r}\left[\tfrac{\alpha}{\lambda} m + \tfrac{\delta}{\lambda} r(1-m)\right] \tag{A.5}$$

with strict equality for δ>0. Then the threshold $\bar{N}_1$ follows from setting δ =0 with strict equality of (A.5), and α =1. Then we have the optimal investment liquidation strategy

$$\delta = \begin{cases} 0 & \text{for } N_1 < \bar{N}_1 \\ \frac{1}{r}\frac{N_1 - \bar{N}_1}{\bar{N}_1}\frac{m}{(1-m)} & \text{for } N_1 \geq \bar{N}_1 \end{cases} \tag{A.6}$$

Then the return schedule in (1.28) follows from substituting (A.4) and (A.6) into (1.25) and (1.26), and using the definitions for $\underline{N}_1$ and $\bar{N}_1$. Finally, the first order condition follows from substituting (1.28) into (1.24), and using the definitions for $\underline{N}_1$ and $\bar{N}_1$. Noting that c_1 and c_2 are continuous at $\underline{N}_1$ and $\bar{N}_1$, we arrive at the first order condition in (1.29) that implicitly defines the optimal reserve ratio. ■

APPENDIX B

Proof of Lemma 2.1

First, rewrite equations (2.2) and (2.3) as

$$\pi c_{t+1}^m = (1-\alpha)\frac{p_t}{p_{t+1}} m_t + \delta r(1-m_t) \tag{A.7}$$

$$(1-\pi) c_{t+1}(R_{t+1}) = \alpha \frac{p_t}{p_{t+1}} m_t + (1-\delta) R_{t+1}(1-m_t) \tag{A.8}$$

Given spatial separation, limited communication and the illiquid nature of investments, it follows that agents will necessarily need currency or liquidated investments to consume if relocated. Since $r < p_t/p_{t+1}$ by assumption, it follows that $m_t > 0$. We have $\delta = 0$ by the same reason.

By $\int R_{t+1} f(R) dR > p_t/p_{t+1}$, it follows that (1- m_t) > 0. Then $\alpha=0$ by sufficiently low levels of risk aversion. It follows that (A.7) and (A.8) can be written as (2.4) and (2.5) ■

Proof of Lemma 2.2

Given a realization of $R_{t+1} < R^*(m)$, then $c_{t+1}^m > c_{t+1}(R_{t+1})$, and non-movers will find it optimal to report to be movers if offered the deposit return schedules (2.4) and (2.5).

Define $\hat{c}_{t+1}^m$ and $\hat{c}_{t+1}(R_{t+1})$ as the incentive compatible returns to movers and non-movers, respectively. To induce non-movers to truthfully report their type, banks will have to set $\hat{c}^m_{t+1} \leq \hat{c}_{t+1}(R_{t+1})$. Bank's resource constraint is given by

$$\pi\hat{c}^m_{t+1} + (1-\pi)\,\hat{c}_{t+1}(R_{t+1}) = \frac{p_t}{p_{t+1}} m_t + (1-\delta)R_{t+1}\,(1-m_t) + \delta r\,(1-m_t) \tag{A.9}$$

where the optimal $\delta = 0$, since $r = \underline{R} \leq R_{t+1}$ for all R_{t+1}. Since truth telling on behalf of non-movers will bind at $\hat{c}^m_{t+1} = \hat{c}_{t+1}(R_{t+1})$, we can write (A.9) as $c^c_{t+1}(R_{t+1})$ given in (2.7). This deposit return will be incentive compatible for $R_{t+1} < R^*(m)$, so no bank runs will occur. ■

Proof of Lemma 2.3

Clearly, banks will be able to service all agents who choose to withdraw in the first period if they offer the return c^r. To verify that non-movers will not have the incentive to run, we first consider the case when $R_{t+1} > R^*(m)$. Here, the utility for a non-relocated agent when it chooses not to run is $U(c_{t+1}(R_{t+1}))$, and the expected payoff when it chooses to run is $\pi U(c^m_{t+1}) + (1-\pi)U(c^r_{t+1})$. Then, by $c_{t+1}(R_{t+1}) > c^m_{t+1} > c^r_{t+1}$ when $R_{t+1} > R^*(m)$, we have that

$$U(c_{t+1}(R_{t+1})) \;>\; \pi U(c^m_{t+1}) + (1-\pi)U(c^r_{t+1}) \tag{A.10}$$

Next, consider the case when $R_{t+1} < R^*(m)$. Here, the expected utility for a non-relocated agent when it chooses not to run is $U(c^c_{t+1}(R_{t+1}))$, and the expected payoff when it chooses to run is $\pi U(c^c_{t+1}(R_{t+1})) + (1-\pi)U(c^r_{t+1})$. Since $r \leq \underline{R}$, then $c^c_{t+1}(R_{t+1}) > c^r_{t+1}$, and we have that

$$U(c^c_{t+1}(R_{t+1})) \;>\; \pi U(c^c_{t+1}(R_{t+1})) + (1-\pi)U(c^r_{t+1}) \tag{A.11}$$

It follows that agents will never find it optimal to run when banks offer to pay c^r to any fraction beyond π of agents to report to be movers. ■

Autarky vs. Intermediation

When agents behave autarkically, the expected return on risky assets is

$$\pi r + (1-\pi)\int_{\underline{R}}^{\bar{R}} R_{t+1} f(R)\, dR \tag{A.12}$$

where with probability π, agents will be relocated and forced to liquidate their investments. In contrast, for the full observation banking environment, the return on risky assets is

$$\int R_{t+1}\, f(R)\, dR \tag{A.13}$$

By $r \leq R$ for all R, we have that

$$\pi r + (1-\pi)\int_{\underline{R}}^{\bar{R}} R_{t+1} f(R)\, dR \leq \int_{\underline{R}}^{\bar{R}} R_{t+1} f(R)\, dR \tag{A.14}$$

Thus, agents are able to access higher expected returns through intermediation. This is because relocation uncertainty occurs at the individual level, but there is no relocation uncertainty in the aggregate. That is, banks provide insurance against relocation and prevent costly liquidation of the risky asset. Because of this, agents will find it optimal to deposit their entire endowments in banks. It follows that in an environment where runs are possible, intermediation will still be preferred for sufficiently low probabilities of runs.

Proof of Lemma 2,4

Given $R_{t+1} < R^*(m)$, then $c_{t+1}^m > c_{t+1}$, thus non-movers will find it optimal to report to be movers. Since all agents report to be movers, the bank's resource constraint becomes

$$c_{t+1}^l = \frac{p_t}{p_{t+1}} m_t + \delta r(1-m_t) \tag{A.15}$$

since no agents will withdraw in the next period, and movers will only accept a contingent payment when they observe banks close, we have that $\delta = 1$, and we can write

$$c_{t+1}^{l} = \frac{p_t}{p_{t+1}} m_t + r(1 - m_t) \tag{2.14}$$

■

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Vita

Matias Fontenla was born in Buenos Aires, Argentina on November 29, 1971, the son of Juan Carlos Fontenla and Petra Angelika Henrici. He attended the Universidad de Buenos Aires starting in 1990, where he completed two years of college. The following years he spent traveling throughout the Americas, and eventually stayed in Salt Lake City, Utah, where he completed his undergraduate degree in Economics and German at the University of Utah in 1997. He then entered graduate school at the University of Texas at Austin, where he earned a Master of Science in Economics in May 2000 and was awarded his Doctor of Philosophy degree in December 2003. His first academic position is as an Associate Professor of Economics at the Universidad de Guanajuato, Mexico.

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