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RATIONAL AND SELF-FULFILLING  
BALANCE-OF-PAYMENTS CRISES

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ABSTRACT

The recent balance-of-payments literature shows that speculative attacks on a pegged exchange rate must sometimes occur if the path of the rate is not to offer abnormal profit opportunities. Such attacks are fully rational, as they reflect the market's response to a regime breakdown that is inevitable. This paper shows that, given certain expectations about policy, balance-of-payments crises can also be purely self-fulfilling events. In such cases even a permanently viable regime may break down, and the economy will possess multiple equilibria corresponding to different subjective assessments of the probability of collapse. The behavior of domestic interest rates and foreign reserves will naturally reflect the possibility of a speculative attack.

Work on foreign-exchange crises derives from the natural-resource literature initiated by Salant and Henderson (1978), where the definition of "abnormal" profit opportunities is straightforward. Because the definition is not always straightforward in a monetary context, this paper also shows how crises occur in a discrete-time stochastic monetary model when an eventual breakdown is inevitable.

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## Introduction

The collapse of a fixed exchange rate is typically marked by one or more balance-of-payments crises in which speculators acquire a large portion of the central bank's foreign reserves as the bank attempts in vain to support its currency. Economists have long attributed such crises to inappropriate domestic policies that ultimately place the central bank in the uncomfortable position of offering speculators a one-sided bet. The recent balance-of-payments literature, beginning with the work of Krugman (1979), tends to support the foregoing view. When asset holders have perfect foresight and the current peg must eventually be abandoned, profit maximization dictates that a sharp attack on the central bank's reserves occur at some point on the economy's path.<sup>1</sup> Speculative attacks appear to be self-fulfilling, since they may occur even when the level of reserves seems sufficient to handle "normal" balance-of-payments deficits. But under the view sketched above, the attacks are inevitable, and represent an entirely rational response to persistently conflicting internal and external macroeconomic targets.

This paper demonstrates the existence of circumstances in which balance-of-payments crises may indeed be purely self-fulfilling events rather than the inevitable result of unsustainable macroeconomic policies. Such crises are apparently unnecessary and collapse an exchange rate that would otherwise have been viable. They reflect, not irrational private behavior, but an indeterminacy of equilibrium that may arise when agents expect a speculative attack to cause a sharp change in government macroeconomic policies.

The paper is organized as follows. Section I sets out a simple stochastic model in which (a) domestic credit may deviate from its constant mean level only by a serially-correlated disturbance with finite

variance, (b) shocks to domestic credit are small in a well-defined sense, and (c) agents do not expect any policy change in the event of a balance-of-payments crisis. In that setting, a run on the central bank's foreign reserves is a probability-zero event. The section goes on to discuss the timing of the exchange rate's inevitable collapse when domestic credit follows a random walk with drift rather than a stationary, finite-variance process.<sup>2</sup> Section II then relaxes assumption (c) by postulating that agents expect an exchange-rate collapse to set off an inflationary domestic-credit policy. Under the new assumption, self-fulfilling runs become a possibility. Indeed, the economy is shown to possess a continuum of equilibria, each corresponding to a different subjective assessment of the likelihood of an exchange-rate collapse. The nominal interest rate in this economy will at times exceed the world rate; and a positive innovation in domestic credit will widen any international interest differential, even while the exchange rate remains fixed. Section III places the self-fulfilling crisis example in the context of related literature on bank runs, bubbles, and extrinsic uncertainty. An appendix discusses some technical questions that arise in the text.

### I. The Economics of Rational Crises

The model employed is the simple linear one developed by Flood and Garber (1984a) and used in Obstfeld (1984a). Under the assumptions made in those papers (and in the earlier literature), speculative attacks on the currency occur in a setting where the eventual abandonment of the current fixed exchange rate is inevitable. Speculation can never occur if market conditions are consistent with the unconditional and indefinite maintenance

of the fixed exchange rate. After briefly setting out the model, this section explains the economics of those results. The next section will give an example of a scenario under which even a perpetually viable exchange rate can be attacked.

A small country enjoys perfect international capital mobility, and its residents consume and produce a single good. If  $S_t$  is the fixed domestic-currency price of foreign exchange and  $P_t^*$  is the foreign-currency price of output, the domestic price level  $P_t$  is given by  $S_t P_t^*$ , for all times  $t$ . If  $i_t^*$  is the nominal interest rate on foreign-currency securities, the domestic nominal interest rate  $i_t$  is given by  $i_t = i_t^* + E_t[(S_{t+1}/S_t) - 1]$ , where  $E_t[\cdot]$  denotes an expectation conditional on time- $t$  information. Both  $P^*$  and  $i^*$  are assumed to be constants, equal to 1 and 0, respectively. Let  $\bar{S}$  denote the level of the initially fixed exchange rate.

Domestic money is held by domestic residents only, and consists entirely of the liabilities of the central bank. Let  $R_t$  be the book value of central-bank foreign reserves and  $D_t$  domestic credit. Equilibrium in this economy is determined by the equality of money demand,

$$M_t^d / P_t = \alpha - \beta i_t, \quad (1)$$

and money supply,

$$M_t^s = R_t + D_t. \quad (2)$$

Assume first that as long as the exchange rate is fixed, domestic credit evolves according to the law

$$D_t = \bar{D} + v_t, \quad (3)$$

where the disturbance  $v_t$  follows the covariance-stationary AR(1) process

$$v_t = \rho v_{t-1} + \varepsilon_t \quad (0 \leq \rho < 1, E_{t-1}[\varepsilon_t] = 0) \quad (4)$$

and the innovations  $\varepsilon_t$  are serially independent. The assumptions made above imply that if the exchange rate is fixed at  $\bar{S}$  and expected to remain so next period, equilibrium reserves are  $R_t = \alpha\bar{S} - D_t$ . In this case, the domestic interest rate and the world rate coincide.

The exchange-rate regime collapses when private domestic wealth owners acquire the entire remaining stock of central-bank foreign reserves.<sup>3</sup> A collapse clearly presupposes the existence of some lower bound on central-bank reserves,  $\bar{R}$ . It is worth noting, though, that there is in principle no reason why a central bank facing perfect international capital markets cannot borrow indefinitely to support the exchange rate, provided it raises taxes to service the external debt it incurs (see Obstfeld [1984b]). Nonetheless,  $\bar{R}$  is assumed to be an exogenous, possibly negative, constant for the purpose of the present analysis. It is assumed further that mean reserves under a permanently fixed rate exceed  $\bar{R}$ , that is, that

$$\alpha\bar{S} - \bar{D} - \bar{R} > 0.$$

In the models of Krugman (1979), Flood and Garber (1984a), and Obstfeld (1984a,b), a steadily growing domestic-credit stock makes a breakdown of the fixed-rate regime inevitable. (I return to this result shortly.) But the alternative credit-growth process given by (3) and (4) does not imply that the fixed exchange rate is unconditionally viable. A large enough realization of the random variable  $\varepsilon_t$  (given  $v_{t-1}$ ) can clearly drive reserves to their limit  $\bar{R}$ , forcing an unexpected abandonment of the fixed rate  $\bar{S}$  and a depreciation. It is convenient to rule out this possibility by assuming that  $\text{Prob} [\varepsilon < (1 - \rho)(\alpha\bar{S} - \bar{D} - \bar{R})] = 1$ . (This implies, by (4), that  $\text{Prob} [v < \alpha\bar{S} - \bar{D} - \bar{R}] = 1$ .) Under this additional assumption

the fixed exchange rate can, with probability one, persist indefinitely.

If the domestic-credit rule described by (3) and (4) is followed regardless of the exchange-rate regime, domestic credit does not grow steadily and an exchange-rate collapse can never occur. To see why this is so, recall first that equilibrium reserves always exceed  $\bar{R}$  if the exchange rate is pegged at  $\bar{S}$  and expected to remain pegged. Suppose now that there is an equilibrium for the economy involving the private acquisition of the official reserve stock on some date  $T$ . I will show that the exchange rate appreciates with probability one as the central bank is forced to withdraw from the foreign exchange market. This implies that the hypothesized run cannot occur along an equilibrium path of the economy. Any investor who anticipates the exchange rate's path will not participate in the attack (even if he believes everyone else will), but will prefer to wait until others have dislodged the exchange rate from its peg so that he can buy foreign assets at a lower domestic-currency price. Because no one will wish to participate in the attack, it cannot occur at time  $T$ .

To see that the floating rate  $\tilde{S}_T$  resulting from a run at time  $T$  lies below  $\bar{S}$ , solve for the economy's rational-expectations equilibrium under free floating. All official reserves in excess of  $\bar{R}$  have been acquired by speculators when floating commences. Together with the assumed international parity conditions, (1) and (2) therefore imply that the floating rate's evolution is governed by the difference equation

$$-BE_t[\tilde{S}_{t+1}] + (\alpha + \beta)\tilde{S}_t = \bar{R} + D_t \quad (t \geq T). \quad (5)$$

The saddle-path solution for  $\tilde{S}_T$  is<sup>4</sup>

$$\tilde{S}_T = (\alpha + \beta)^{-1} \sum_{j=0}^{\infty} \left(\frac{\beta}{\alpha + \beta}\right)^j E_T[\bar{R} + D_{T+j}]. \quad (6)$$

Under assumptions (3) and (4),  $\tilde{S}_T$  can be written

$$\tilde{S}_T = \alpha^{-1}(\bar{R} + \bar{D}) + [\alpha + \beta(1 - \rho)]^{-1} v_T.$$

Because  $\bar{S} > \alpha^{-1}(\bar{R} + \bar{D})$ ,  $\tilde{S}_T < \bar{S}$  if  $v_T < 0$ . It was assumed above that  $v_T < \alpha\bar{S} - \bar{D} - \bar{R}$  with probability one. It follows that if  $v_T > 0$ ,  $\tilde{S}_T < \alpha^{-1}(\bar{R} + \bar{D} + v_T) < \bar{S}$  with probability one. Since the exchange rate must appreciate immediately if the central bank loses all reserves at T, equilibrium runs are probability-zero events. A consequence is that the domestic and foreign interest rates must always coincide in the present setting.

The key element in the above argument was the stipulation that no abrupt policy change is expected to occur as the result of a crisis: the domestic credit process described by (3) and (4) does not change, and the central bank withdraws from the foreign exchange market when its reserves are exhausted. Once the foregoing stipulation is dropped, the equilibrium of the economy may become indeterminate. As a result, runs become possible, even if the exchange rate would have been viable forever in their absence.

Before demonstrating this possibility in the next section, it will be useful to describe how an exchange-rate collapse occurs in the present model if domestic credit grows monotonically over time. This is the scenario studied by Flood and Garber (1984a). Consider an economy in which domestic credit evolves according to the rule



$$D_t = D_{t-1} + \mu_t (E_{t-1}[\mu_t] = \mu > 0), \quad (7)$$

where  $\text{Prob} [\mu_t \geq 0] = 1$ , for all  $t$ . In terms of (3) and (4),  $\rho$  assumes the value 1 and the mean of  $\epsilon$  shifts upward. It is assumed again that (7) holds regardless of the exchange-rate regime, and that no foreign-exchange intervention occurs after a collapse.

If the exchange rate floats at any time  $t$  (and if central-bank reserves accordingly are constant at their lower limit  $\bar{R}$ ), the equilibrium rate  $\tilde{S}_t$  is again given by (6). Under the monetary regime (7), however,

$$\tilde{S}_t = \alpha^{-1}(\bar{R} + D_t) + \alpha^{-2}\beta\mu. \quad (8)$$

Suppose first that  $\tilde{S}_t \leq \bar{S}$ . As in the previous discussion, the exchange rate cannot be floating in period  $t$ . If the equilibrium floating rate when reserves equal  $\bar{R}$  is below  $\bar{S}$ , reserves would exceed  $\bar{R}$  in an equilibrium with the exchange rate pegged at  $\bar{S}$ . This would be true even if the exchange rate were expected to float in  $t+1$ , since the expected depreciation between  $t$  and  $t+1$  would be reduced by a rise in the rate from  $\tilde{S}_t$  to  $\bar{S}$ . Thus the central bank can certainly peg the rate at  $\bar{S}$  through period  $t$  unless the public acquires the reserve stock in an attack. But no individual would find it profitable to join in an attack that causes an instantaneous exchange-rate appreciation. (The bank will lose its remaining reserves in an attack if  $\tilde{S}_t = \bar{S}$ , but the exchange rate remains at  $\bar{S}$  until the next period. I therefore consider it "nonfloating" on date  $t$ , a matter of definition.)

What if  $\tilde{S}_t > \bar{S}$ ? Flood and Garber (1984a) note correctly that the exchange rate must float in the first period that this inequality holds.

However, the rationale they offer for this assertion -- that the condition  $\tilde{S}_t > \bar{S}$  offers speculators an opportunity to profit at official expense -- merely shows (recall the previous paragraph) that if a run is expected, it will pay for all to join in. In other words, while a path for the economy such that the exchange rate collapses the first time  $\tilde{S}_t > \bar{S}$  is an equilibrium path, it remains to show that no other outcome is consistent with intertemporal equilibrium.

This is easily done once a precise definition of "equilibrium" is adopted. At any time  $t$  the state of the economy is defined by the current realization of domestic credit  $D_t$ . Following Salant (1983), define an equilibrium exchange-rate function  $S(D_t)$  by the properties:

(a) for all realizations  $D_t$ , there is a reserve level  $R_t \geq \bar{R}$  such that

$$R_t + D_t = \alpha S(D_t) - \beta E_t [S(D_{t+1}) - S(D_t)];$$

and (b)  $S(D_t) = \bar{S}$  if  $R_t > \bar{R}$ . Then under the central-bank behavior assumed above, the following result can be demonstrated:

Theorem. If  $S(D_t)$  is an equilibrium exchange-rate function, there is a critical domestic-credit level  $\tilde{D}$  such that  $S(D_t) > \bar{S}$  if and only if  $D_t > \tilde{D}$ . The threshold  $\tilde{D}$  is defined by

$$\tilde{D} \equiv \inf \{D: \alpha^{-1}(\bar{R}+D) + \alpha^{-2}\beta\mu > \bar{S}\}.$$

It follows from (8) that  $S(D_t) = \tilde{S}_t$  whenever  $\tilde{S}_t > \bar{S}$ .

Proof. It has already been shown that  $S(D_t) = \bar{S}$  in equilibrium if  $D_t \leq \tilde{D}$  (so that  $\tilde{S}_t \leq \bar{S}$ ). To prove that  $S(D_t) > \bar{S}$  whenever  $D_t > \tilde{D}$  (in which case  $R_t = \bar{R}$  and  $S(D_t) = \tilde{S}_t$ ), assume the contrary. Thus, let  $\tilde{D}' > \tilde{D}$  be the smallest level of domestic credit such that  $S(\tilde{D}') > \bar{S}$  (more precisely, the infimum of the set of  $D$  with  $S(D) > \bar{S}$ ; this set is nonempty because reserves are limited). I will show that there are realizations of domestic cre-

dit  $D_t$  between  $\tilde{D}$  and  $\tilde{D}'$  such that  $S(D_t) = \bar{S}$  is inconsistent with money-market equilibrium.

So let  $D_t \in (\tilde{D}, \tilde{D}')$ . Since  $R_t \geq \bar{R}$ , money-market equilibrium requires

$$\bar{R} + D_t \leq \alpha \bar{S} - \beta E_t[S(D_{t+1}) - \bar{S}] \quad (9)$$

if  $S(D_t) = \bar{S}$ . Define  $\delta(D_t) \equiv \text{Prob} [\mu_{t+1} \geq \tilde{D}' - D_t]$ . Then  $E_t[S(D_{t+1})] = [1 - \delta(D_t)]\bar{S} + \delta(D_t)E_t[\tilde{S}_t \mid \mu_{t+1} \geq \tilde{D}' - D_t] = [1 - \delta(D_t)]\bar{S} + \delta(D_t)\{\alpha^{-1}(\bar{R} + D_t) + \alpha^{-1} E[\mu_{t+1} \mid \mu_{t+1} \geq \tilde{D}' - D_t] + \alpha^{-2}\beta\mu\}$ . Let  $g(\cdot)$  denote the probability density function for  $\mu_{t+1}$ . Then the necessary condition (9) can be written:

$$\tilde{S}_t \leq \bar{S} + \frac{\beta}{\alpha[\alpha + \beta\delta(D_t)]} \int_0^{\tilde{D}' - D_t} \mu_{t+1} g(\mu_{t+1}) d\mu_{t+1} . \quad (10)$$

As figure 1 shows, the left-hand side of (10) rises linearly with  $D_t$ , and  $\tilde{S}_t \geq \bar{S}$  for  $D_t = \tilde{D}$ . The right-hand side of (10) is nonincreasing, reaching its minimal value  $\bar{S}$  when  $D_t = \tilde{D}'$ . It is clear that any exchange-rate function with  $S(D_t) = \bar{S}$  for  $D_t < \tilde{D}'$  does not define an equilibrium because condition (10) is violated when  $D_t \in (D', \tilde{D}')$ .<sup>5</sup>

It is clear that the form of domestic-credit rule (7) was a key ingredient in the above demonstration that the exchange rate must float as soon as  $\tilde{S}_t$  exceeds  $\bar{S}$ . The observation that everyone would wish to participate in a run if one were expected does not, itself, prove that a run must occur. The next section underlines this point by providing an example of an economy in which the exchange rate can remain fixed even if its floating-rate "shadow" value exceeds  $\bar{S}$ .

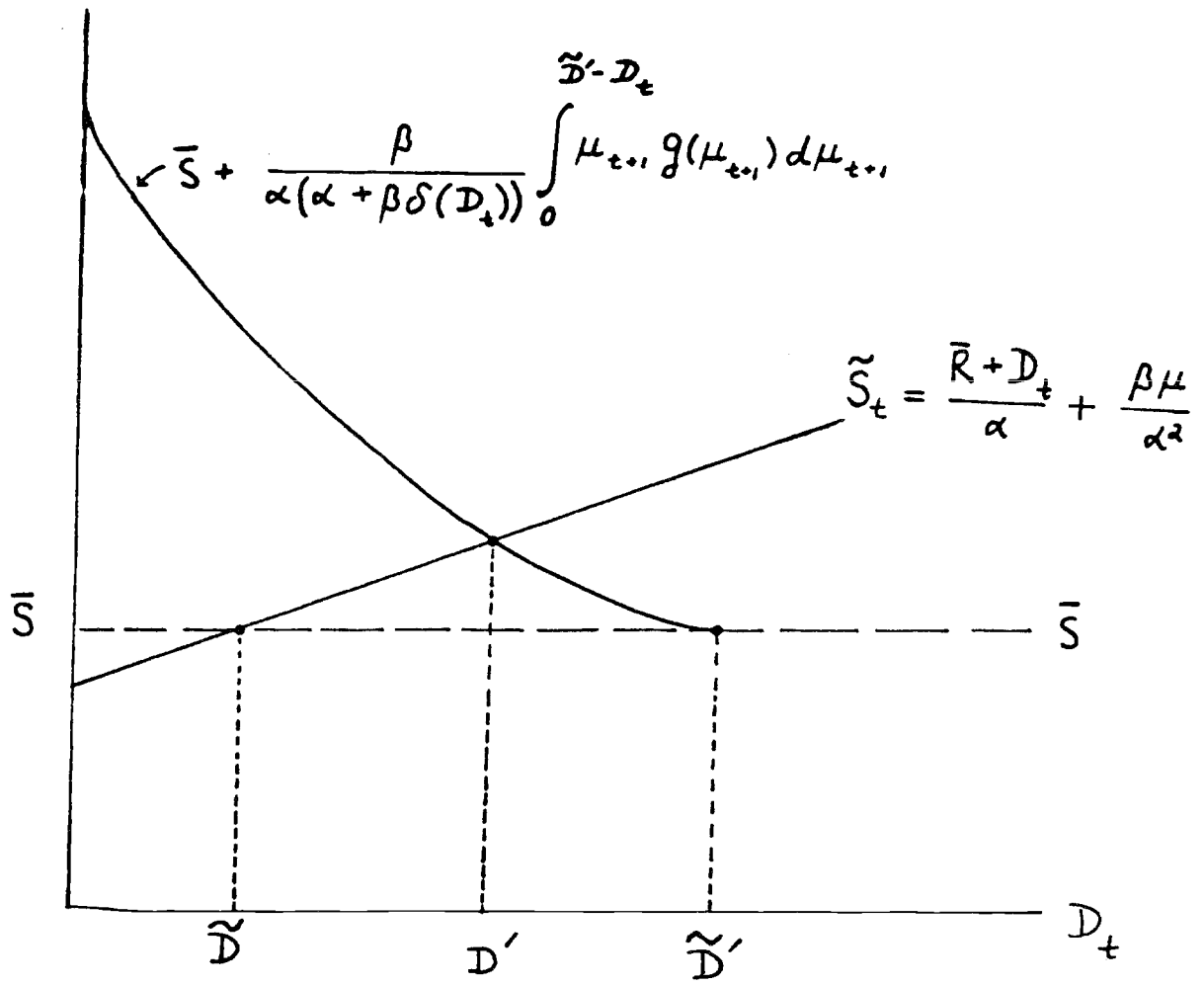


Figure 1

## II. Self-Fulfilling Crises: An Example

This section gives an example of a crisis-induced policy change which, if anticipated, leads to indeterminacy of equilibrium and the possibility of self-fulfilling or seemingly unnecessary runs. The example involves the expected adoption of an inflationary domestic-credit growth rule in the event of a crisis. Initially, however, the exchange rate is fixed at  $\bar{S}$  and the domestic-credit process is again described by (3) and (4).

Assume now that the public holds the following expectation: if a crisis occurs at any time  $T$ , the central bank allows the exchange rate to float forever and switches to the domestic-credit growth rule (7).

There are a number of stories that might buttress this assumption of an expected regime change. For example, when reserves hit  $\bar{R}$ , the central bank can no longer borrow externally, and the government may need to resort to inflationary finance.<sup>6</sup> This need is exacerbated by the sharp rise in official net foreign indebtedness caused by the loss of reserves to private speculators. The recent experiences of Argentina and Chile confirm that financial disorder and capital flight may foreshadow heightened future inflation [see, for example, Diaz-Alejandro (1984)]. While the one-way causation postulated here is inadequate as a description of those countries' experiences, the example serves to elucidate a factor that may have played an important role.<sup>7</sup>

One equilibrium path for the economy is the one described in the preceding section. If the public expects that no collapse will ever occur, there is no run and no switch in the domestic-credit process. Expectations are self-fulfilling, and the fixed-rate regime never collapses.

I now argue that there are infinitely many alternative equilibria, each

corresponding to a different set of public beliefs about the probability of a run. These, too, are self-fulfilling equilibria. Under the policy scenario assumed here, the authorities are expected to validate any run ex post by shifting to an inflationary policy. The argument of the previous section, which ruled out crises in the policy environment described by unconditional adherence to (3) and (4), no longer applies.

As a first step in the construction of an alternative equilibrium, note that in the event of an exchange-rate collapse at time T, the value of the floating exchange rate is again given by (8), which is reproduced here with the substitution  $D_T = \bar{D} + v_T$ :

$$\tilde{S}_T = \alpha^{-1}(\bar{R} + \bar{D} + v_T) + \alpha^{-2}\beta\mu.$$

Because a crisis now induces expectations of future inflation, it is possible that the exchange rate depreciates if the central bank is forced to leave the foreign exchange market. This occurs if  $\tilde{S}_T > \bar{S}$ , that is, if

$$\alpha^{-1}(\bar{R} + \bar{D} + v_T) + \alpha^{-2}\beta\mu > \bar{S}.$$

Clearly the foregoing inequality can hold even when the equilibrium reserve level in the no-run equilibrium,  $\alpha\bar{S} - \bar{D} - v_T$ , exceeds  $\bar{R}$ ; it implies that a run may take place whenever

$$v_T > (\alpha\bar{S} - \bar{R} - \bar{D}) - \alpha^{-1}\beta\mu \equiv \bar{C}. \quad (11)$$

Because  $\mu > 0$ , inequality (11) may hold even under the boundedness assumption on  $\epsilon$  made in section I.

Consider now the following sequence of events. At the start of a period T, the value of current domestic credit is revealed. Simultaneously,

an exogenous lottery determines the state of nature. There are two possible ~~states~~. In state 1, which occurs with probability  $\pi$ , a run on the central bank's reserves occurs if, and only if,  $v_T > \bar{C}$  [inequality (11)]. In state 2, which occurs with probability  $1 - \pi$ , no run occurs. If state 1 occurs and  $v_T > \bar{C}$ , every agent will find it advantageous to participate in the run by selling the central bank as much domestic money as possible. Because the exchange rate is expected to depreciate once the central bank can no longer peg it at  $\bar{S}$ , agents will flee the domestic currency to avoid a sure capital loss.

The distribution of events described above clearly defines a stochastic equilibrium in the special case  $\pi = 0$ , namely, the no-run equilibrium of the previous section. If positive choices of  $\pi$  also define equilibria, runs can occur, and the domestic interest rate  $i$  can lie above the world rate  $i^*$  even while the exchange rate is fixed. This would be necessary to compensate domestic bond holders for capital losses expected in the event of a crisis.<sup>8</sup>

Do there exist equilibria with  $\pi > 0$ ? The technical obstacle to resolving this question is connected with the foregoing observation concerning the domestic interest rate  $i$ . If  $\pi > 0$ , shocks to domestic credit may alter the domestic interest rate, and thus need not lead to equal offsetting changes in reserves. If a positive domestic credit innovation raises  $i$  (a conjecture that will be verified below), the upper bound on  $\epsilon$  assumed in section I no longer prevents unexpectedly high domestic credit creation from driving reserves to  $\bar{R}$  and wiping out the fixed-rate regime without warning. If inequality (11) can hold only for shocks that drive reserves below  $\bar{R}$ , the notion of equilibria with  $\pi > 0$  is vacuous.

To avoid this problem, it is sufficient to restrict the range of  $\varepsilon$  more tightly. Assume there exists a positive  $\bar{B}$  satisfying  $\bar{C} < \bar{B} < \alpha\bar{S} - \bar{D} - \bar{R}$  such that  $\text{Prob}[\varepsilon < (1 - \rho)\bar{B}] = 1$ . As is shown in the appendix, there exists a  $\bar{\pi} > 0$  so small that for  $\pi < \bar{\pi}$ , reserves are no less than  $\bar{R}$  in equilibrium if state 1 has never occurred and the exchange rate is fixed at  $\bar{S}$ . The crisis probabilities  $\pi$  in the interval  $[0, \bar{\pi})$  define a continuum of possible stochastic equilibria for the economy in which the exchange rate is fixed if state 1 has never occurred.

With this more stringent restriction on  $\varepsilon$ , it is straightforward to compute the domestic interest rate for  $\pi$  in  $[0, \bar{\pi})$  while the exchange rate is fixed. Let  $D_t = \bar{D} + v_t$  summarize the state of the economy on a date  $t$  when no run occurs. If  $v_{t+1} < \bar{C}$ , a crisis cannot occur next period, so  $S_{t+1}$  will remain at  $\bar{S}$ . If  $v_{t+1} > \bar{C}$ , a crisis will occur with probability  $\pi$ .<sup>9</sup> Define  $q(v_t) \equiv \text{Prob}[\varepsilon_{t+1} > \bar{C} - \rho v_t]$ . Then by (8),

$$E_t[S_{t+1}] = [1 - \pi q(v_t)]\bar{S} + \pi q(v_t)\{\alpha^{-1}(\bar{R} + \bar{D} + \rho v_t + E[\varepsilon_{t+1} | \varepsilon_{t+1} > \bar{C} - \rho v_t]) + \alpha^{-2}\beta\mu\}. \quad (12)$$

Equation (12) states that the exchange rate expected to prevail next period (given that no run has yet occurred) is a weighted sum of  $\bar{S}$  and the rate expected to equilibrate asset markets in the event of an exchange-rate collapse. As the latter cannot be lower than the peg  $\bar{S}$ ,  $E_t[S_{t+1}] \geq \bar{S}$  and so  $i_t = i_t^* + E_t[(S_{t+1}/\bar{S}) - 1] \geq i_t^*$ <sup>10</sup>

Because domestic credit shocks are serially correlated, a higher value of  $v_t$  (given that there is no run) raises the probability that  $v_{t+1}$  will exceed the critical level  $\bar{C}$  at which a run becomes possible. In fact, an



increase in  $v_t$  causes a rise in next period's expected exchange rate, and thus a rise in the interest rate  $i_t$ . To see this, let  $f(\cdot)$  denote the (continuous) probability density function of the random variable  $\epsilon$ . Then

$$q(v_t) = \frac{(1 - \rho)\bar{B}}{\bar{C} - \rho v_t} \int f(\epsilon) d\epsilon \quad (\text{or } 0, \text{ if } \bar{C} - \rho v_t \geq (1 - \rho)\bar{B})$$

and

$$E[\epsilon_{t+1} \mid \epsilon_{t+1} > \bar{C} - \rho v_t] = \int_{\bar{C} - \rho v_t}^{(1 - \rho)\bar{B}} \frac{\epsilon f(\epsilon)}{q(v_t)} d\epsilon \quad (\text{if } q(v_t) > 0)$$

so that differentiation of (12) implies

$$\frac{d(E_t[S_{t+1}])}{dv_t} = \alpha^{-1} \pi \rho q(v_t) \geq 0, \quad (13)$$

for any  $\pi$ . A consequence of (13) is that a positive domestic-credit shock may actually reduce money demand, occasioning a more-than-offsetting reserve loss.

### III. Discussion

The previous section presented an example of an economy in which self-fulfilling expectations give rise to a continuum of possible equilibria. Even though a crisis is not inevitable, agents believe that the central bank will respond to crises by embarking on a program of heightened inflation. The belief that the authorities will (in effect) ratify crises makes it unprofitable for any individual speculator to hold domestic currency while a run is taking place.

In this context, balance-of-payments crises are very similar to bank runs. Diamond and Dybvig (1983) present a stylized, static model of finan-

cial intermediation in which there are two equilibria: one in which agents have confidence in the solvency of financial intermediaries, and one in which lack of confidence leads to a run. Both equilibria involve self-fulfilling expectations because banks fail if, and only if, there is a run. As section I showed, balance-of-payments crises, unlike bank runs, need not be self-ratifying. The stability of a pegged-rate regime hinges on the anticipated response of the authorities.

The model of section II differs from that of Diamond and Dybvig in that it is dynamic; and if runs are to be made possible, it is necessary to endow agents with rational subjective probabilities of runs. This was accomplished by randomizing over the run and no-run equilibria. Blanchard (1979) uses this device to construct an example of an asset-market bubble that "crashes" with probability one. He assumes that when the asset price is on a bubble path, there is a time-invariant probability that it will return to its fundamental or saddle-path value next period. The type of uncertainty determining the equilibrium agents believe will prevail has been labelled "extrinsic" uncertainty by Cass and Shell (1983). Those authors study the allocative effects of extrinsic uncertainty in a utility-maximizing model with restricted market participation. Their results suggest that a maximization-based version of the present paper's model may give some deeper insights into the nature of self-fulfilling balance-of-payments crises.

In their study of gold monetization, Flood and Garber (1984b) give an example of a self-fulfilling run similar to the one explored above. The paper shows how an otherwise viable gold standard might break down if agents anticipate that it will collapse some time in the future. As in the

example of self-fulfilling balance-of-payments crises, and for the same reason, indeterminacy arises only when agents expect the authorities to resort to inflationary finance in the wake of a regime collapse. While Flood and Garber's gold model is nonstochastic, the introduction of extrinsic uncertainty would result in additional equilibrium paths.

Flood and Garber (1984a) suggest that the timing of a run may be indeterminate for reasons different from those explored above. If the floating exchange rate prevailing after a run can reflect nonstationary speculative bubbles as well as market fundamentals, the equilibrium floating rate is indeterminate. This implies that runs can in principle occur at any time. The example studied in this paper explicitly assumes that the floating exchange rate depends entirely on its fundamental determinants, however [equation (6)].<sup>11</sup> Obstfeld and Rogoff (1983, 1984), using a maximizing model, show how the government can prevent such bubbles by using its fiscal powers to guarantee a minimal real redemption value for money.

The fractional backing described by Obstfeld and Rogoff (1983, 1984) is an example of an official guarantee which, though never exercised, precludes inefficient equilibria supported by self-fulfilling expectations. The deposit insurance scheme studied by Diamond and Dybvig (1983) is another example in this class. These papers make the important argument that anticipated government policies can block the emergence of certain sub-optimal competitive equilibria. In a sense, the present paper turns that argument on its head. Expected government actions may lead to undesired outcomes in economies that would function correctly otherwise.

Appendix

This appendix demonstrates that the crisis probability  $\pi$  can always be chosen so small that if the first "state of nature" described in section II has not occurred, non-collapse of the fixed-rate regime is consistent with money-market equilibrium.

In order that this be true, equilibrium reserves in state 2 (the no-run state of nature) must always exceed  $\bar{R}$  for sufficiently small  $\pi$ . By (1)-(3), this means that when  $E_t[S_{t+1}]$  is given by (12),

$$R_t = \alpha\bar{S} - \bar{D} - v_t - \beta(E_t[S_{t+1}] - \bar{S}) > \bar{R} \quad (14)$$

for all  $t$ . I argue that there exists a positive  $\bar{\pi}$  such that (14) always holds for  $\pi < \bar{\pi}$ .

Let  $E_t[\tilde{S}_{t+1} \mid \varepsilon_{t+1} > \bar{C} - \rho v_t]$  denote the equilibrium floating exchange rate expected to materialize on date  $t+1$  if a run occurs. By (12), (14) can be written

$$\alpha\bar{S} - \bar{D} - v_t - \beta\pi q(v_t)(E_t[\tilde{S}_{t+1} \mid \varepsilon_{t+1} > \bar{C} - \rho v_t] - \bar{S}) > \bar{R}. \quad (15)$$

Equation (12) and inequality (13) imply that  $q(v_t)(E_t[\tilde{S}_{t+1} \mid \varepsilon_{t+1} > \bar{C} - \rho v_t] - \bar{S})$  can be written as a function of  $v_t$ ,  $\Phi(\cdot)$ , where  $\Phi'(\cdot) \geq 0$ . With this definition, (15) becomes

$$\alpha\bar{S} - \bar{D} - \bar{R} > v_t + \beta\pi\Phi(v_t). \quad (16)$$

Recall that  $\varepsilon$  is bounded above by  $(1 - \rho)\bar{B}$ ; it follows that  $v_t$  can never exceed  $\bar{B}$ . Since  $\Phi(\cdot)$  is nondecreasing, it attains its maximum possible value at  $v_t = \bar{B}$ . Let  $\bar{\pi}$  be the positive solution to

$$\alpha\bar{S} - \bar{D} - \bar{R} - \bar{B} - \beta\bar{\pi}\Phi(\bar{B}) = 0.$$

It is now clear that for any  $\pi < \bar{\pi}$ , (16) holds with probability 1. Thus ~~if~~  $\pi < \bar{\pi}$ , the fixed-rate regime is always consistent with money-market equilibrium.

Footnotes

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<sup>1</sup>The literature on rational balance-of-payments crises derives from Salant and Henderson (1978), who discuss the concept of a rational speculative attack in the context of the gold market. Salant (1983) provides further developments. The analogy between external payments crises and attacks in resource markets is closest in the continuous-time, nonstochastic setting explored by Krugman (1979), Flood and Garber (1984a, section II), and Obstfeld (1984a), among others. The essential reason is that it is only in continuous time that an anticipated discrete exchange-rate jump generally entails "abnormal" profit opportunities. Obstfeld (1984b) presents a discrete-time maximizing model in which the collapse of the exchange rate may involve two successive speculative attacks: one on the first day of floating, and one the period before. In stochastic models such as those described below the notion of "speculative attack" becomes even more blurred if one defines speculation as any reduction in private money demand in anticipation of the fixed rate's possible collapse. In this sense, there may be any number of "attacks" before the rate finally does collapse.

<sup>2</sup>Flood and Garber (1984a, section III) have already studied this problem, but their discussion is incomplete at one point. Because the

logical step they omit is critical for understanding the self-fulfilling equilibria of section II, I discuss it at length in section I.

<sup>3</sup>The central bank may commit only a portion of its reserves to the defense of the exchange rate, as in Krugman (1979) and Obstfeld (1984a). For the present analysis, I assume this is not the case.

<sup>4</sup>The general solution to difference equation (5) is the saddle-path solution (6) plus a term of the form

$$K\left(\frac{\alpha + \beta}{\beta}\right)^T,$$

where  $K$  is an arbitrary constant. The saddle-path solution excludes self-fulfilling nonstationary bubbles by imposing the initial condition  $K = 0$ .

<sup>5</sup>Figure 1 incorporates the assumption that the density function  $g(\cdot)$  is continuous; but the proof is easily extended to encompass discrete distributions. Using the techniques in Salant (1983), a theorem like the one in the text could be proved for credit processes more general than (7).

However, this would require the assumption that the central bank pegs the exchange rate at  $\bar{S}$  whenever possible. The restriction that  $\text{Prob}[\mu_{t-} \geq 0] = 1$ , also imposed by Flood and Garber (1984a), makes the latter assumption unnecessary.

<sup>6</sup>The evaporation of the government's credit lines does not, by itself, imply that the private sector can no longer lend abroad or hold external assets and liabilities. Thus, the home interest rate may remain linked to  $i^*$  by interest parity. This would not be the case if the government were to impose capital controls. Wyplosz (1983) examines the role of controls in crises.

<sup>7</sup>Other examples are possible. Multiple equilibria also arise if agents

expect a run to provoke an immediate discrete devaluation, but expect no devaluation otherwise. See Obstfeld (1984a) for a related discussion of devaluation.

<sup>8</sup>Calvo (1983) discusses the possibility that an expected devaluation of uncertain timing can lead to rises in the domestic nominal interest rate and the ex post real interest rate. Lizondo (1983) relates the behavior of foreign-exchange futures prices under fixed exchange rates to similar considerations. Of course, in the Flood and Garber (1984a) model discussed above,  $i$  exceeds  $i^*$  whenever there is a chance that the fixed exchange rate will collapse next period.

<sup>9</sup>It is being assumed that the borderline case  $\varepsilon_{t+1} = \bar{C} - \rho v_t$  has a zero probability weight.

<sup>10</sup>Given the assumed upper bound on the possible realizations of  $\varepsilon$ , it is possible that  $v_t$  is so small that  $q(v_t) = 0$ . In this case  $E_t[S_{t+1}] = \bar{S}$  and  $i_t = i_t^*$ . Inequality (13) below remains valid, however.

<sup>11</sup>In proving the Theorem of section I it was assumed that the equilibrium exchange rate is a function of domestic credit alone. This amounts to excluding from consideration both nonstationary bubbles and extrinsic uncertainty.



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