THE LOGIC OF CURRENCY CRISES

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The dramatic currency crisis that culminated in the August 1993 widening of exchange-rate bands within the European Monetary System (EMS) challenges economists to rethink their models of how markets may force governments to alter supposedly fixed exchange rates. Some European governments, notably Italy's, clearly lacked the full confidence of the markets as a result of fiscal trends incompatible with a fixed exchange rate in the long run. But the scale and scope of the turmoil that began in the summer of 1992 were so great that ultimately even apparently sustainable currency pegs were shaken. The disparate circumstances of the many currencies successfully attacked by speculators has led observers such as Eichengreen and Wyplosz (1993) and Portes (1993) to argue that, at least in the European context, recent speculative crises have been driven in part by self-fulfilling forces.

Economists have rightly tended to be wary of such accounts: finance ministers past and present have preferred to blame crises on Gnomes of Zurich or *agioteurs* rather than face the reality of fundamental factors, including policy errors. A seminal paper by Krugman (1979) provided a convincing theoretical rationale for the economists' view. Krugman set out a simple model in which a currency peg must be abandoned once the pegging nation's foreign exchange reserves run out. He went on to analyze how the peg collapses in situations where the eventual exhaustion of reserves is inevitable. His remarkable finding was that speculators with foresight inevitably attack the currency before reserves are fully depleted and purchase all remaining reserves at that moment—a moment that can be defined precisely. This prediction follows from the simplest principles of currency arbitrage (1).

In this paper I argue that one cannot adequately understand recent European currency experience in terms of Krugman's model. For industrial European countries with access to world capital markets, reserve adequacy *per se* is far less of a concern than it was in the early 1970s; this factor no longer deserves the primacy assigned it in Krugman's analysis (2). Clearly a number of other factors, notably the effects of high interest rates and growing unemployment, came into play in determining how different governments responded to the 1992-93 crisis.

Once one acknowledges that governments may borrow reserves and exercise other policy options in the face of a crisis, the question arises: what factors determine a government's decision to abandon a

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(1) Agénor, Bhandari, and Flood (1992) and Blackburn and Sola (1993) survey the large literature growing out of Krugman's paper.

(2) Under perfect capital mobility, a central bank whose only reason for departing from a currency peg is reserve inadequacy could simply sell domestic assets from its portfolio and attract an equal reserve inflow. This action, which amounts to borrowing reserves with domestic currency, leaves unchanged both the public sector's net debt to the private sector and the national net foreign wealth position. If the peg is in question for reasons other than reserve adequacy, however, the transaction can have strategic implications; see section 2.1 below. Buiter (1987) analyzes a model in which domestic debt issue is more costly than foreign-currency borrowing, so that an open-market sale of domestic debt worsens the public finances.

currency peg or hang on? In a setting of purposeful action by the authorities, however, the possibility of self-fulfilling crises cannot be easily dismissed. Speculative anticipations depend on conjectured government responses, which depend, in turn, on how price changes that are themselves fueled by expectations affect the government's economic and political positions. This circular dynamic implies a potential for crises that need not have occurred, but that do occur because market participants expect them to.

The paper is organized as follows. Section 1 begins by analyzing speculative attacks in exhaustible resource models, where attacks are inevitable as a result of resource depletion. These models are compared with Krugman's model, in which a process of reserve depletion is imposed with no modeling of the basis for government policy decisions. A brief review of Sweden's 1992 currency crisis serves to illustrate some restrictive features of the standard model and to suggest factors that should play a role in more general models of currency crisis.

Section 2 presents two different models in which crisis and realignment result from the interaction of rational private economic actors and a government that pursues well-defined policy goals (1). In the first of these models, high nominal interest rates associated with devaluation expectations can force a government to devalue a currency whose peg would have been viable under another set of private expectations. This model is based on the effects of high interest rates on the government's fiscal position, but one could devise similar models in which high interest rates induce the government to realign though their impact on the banking system, firms' balance sheets, mortgage interest rates, and so on.

A second model shows how realignments may reflect the authorities' desire to offset shocks to competitiveness and employment. This model, too, is subject to multiple equilibria. In it, arbitrary expectational shifts can turn a fairly credible exchange-rate peg into a fragile one (2).

1. HOW UNSUSTAINABLE POLICIES LEAD TO CRISES

In the most basic model of currency crisis, authorities pursue unsustainable macroeconomic policies that must eventually force a fixed exchange rate to be abandoned. Krugman (1979) showed that in a world of perfect foresight, the moment of transition between the fixed-rate regime and its successor generally involves a speculative attack in which private participants in the foreign exchange market acquire in an instant all the foreign-currency reserves central banks commit to the existing parity's defense.

1.1. Speculative Attacks in Gold and Other Exhaustible Resource Markets

Krugman's model was inspired by the literature on government price-fixing schemes in exhaustible resource markets (Salant and Henderson 1978, Salant 1983). Both the logic and limitations of his account are placed in perspective by first reviewing the standard partial-equilibrium model of attacks on government resource stockpiles.

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(1) In two earlier papers (1986, 1988) I presented models in which speculative attacks trigger government responses that effectively validate those attacks. Dellas and Stockman (1993) build on my 1986 analysis to show how the possibility that a government will introduce capital controls in a crisis can generate self-fulfilling attacks. These papers do not, however, derive official responses from models of optimal government behavior, as I do here. Probably the earliest attempt formally to analyze the realignment decision in a strategic context is in a neglected chapter of a book by Gale (Gale 1982, chapter 3). Gale concluded, as I do below in more fully specified models, that devaluations could be self-fulfilling phenomena.

(2) Ozkan and Sutherland (1993) and Bensaid and Jeanne (1993) explore models in which higher nominal interest rates depress output, so that governments abandon pegged exchange rates if nominal interest rates reach too high a level. Both models produce realistic interest-rate dynamics prior to a collapse: those in the first come from the stochastic evolution of foreign interest rates, those in the second from market learning about the fixed cost policymakers incur when they realign. A similar fixed cost figures in the models of section 2, below; the Bensaid-Jeanne model shares with those models the prediction that self-fulfilling attacks may occur. In earlier work, Gros (1992) studies a dynamic model in which realignment is driven by interest rates and self-fulfilling attacks are possible. While Gros did not explicitly cast his model in a setting of policy optimization, it would not be hard to rationalize his assumptions in terms of policy objectives like those assumed by Ozkan and Sutherland and by Bensaid and Jeanne.

In that model the government wishes to peg the price of a resource—call it "gold"—at a price p measured in terms of a broad commodity basket [1]. The private sector's flow demand curve for gold is

$$D(p_t), D'(p_t) < 0,$$

and there is a "choke price" p^c such that $D(p^c) = 0$. At time $t = 0$ the total stock of gold in the (world) economy is S_0; for simplicity, the marginal cost of extracting gold from the ground for private use is assumed to be zero.

The *laissez-faire* perfect-foresight solution for the price path p_t is well known from the classic work of Hotelling (1931). The key insight used in deriving this path is that because gold in the ground yields no service flow and costs nothing to extract, its price p_t must rise at the real rate of interest, r [2]. A rate of price increase greater than r would lead to an excess flow demand for gold by industry and personal users as gold owners hoard it to earn excess returns; a rate of price increase below r would lead to an excess supply as owners dump their gold on the market in order to shift into bonds.

The *laissez-faire* gold price can be determined from the above arbitrage argument, which implies a price path from $t = 0$ of the form

$$p_t = p_0 e^{rt},$$

and the requirement that supply equals demand at each moment. Let T be the date p_t following (2), reaches the zero-demand choke price p^c,

$$p^c = p_0 e^{rT},$$

or,

$$(1) \qquad T = log(p^c/p_0)/r.$$

Then supply will equal demand on every date if the initial market price p_0 is set to equate intertemporal demand to the total available stock:

$$S_0 = \int_0^{log\,(p^c/p_0)/r} D(p_0 e^{rt})dt.$$

On date $T = log\ (p^c/p_0)/r$, the economy's stock of gold is used up and demand is nil. To take a simple concrete example, if $D(p) = p^{-\sigma}$ (in which case $p^c = +\infty$),

$$(2) \qquad p_0 = \tilde{p}(S_0) = (r\sigma S_0)^{-1/\sigma}.$$

Now consider how the equilibrium would look if the government pegs the price of gold at some level $\bar{p}$ between $\tilde{p}(S_0)$ and p^c. Initially gold owners will sell their entire stock S_0 to the government because they can earn a rate of return $r > 0$ by placing their wealth in bonds instead of gold. For a time, industrial and personal demands therefore will be supplied entirely by the government, which must sell an amount $D(\bar{p})$ of its reserve each period. It is clear, however, that this situation is unsustainable: eventually the stock S_0 will be depleted and the equilibrium price will have to be at its choke level. The critical problem is to characterize the process through which the government's price-fixing scheme collapses.

Figure 1 furnishes a simple characterization based on the assumption that $D(p) = p^{-\sigma}$. Its two solid graphs show two notional prices of gold. The horizontal line is the natural logarithm of the official price $\bar{p}$. The second upward-sloping curve is the natural logarithm of $\tilde{p}_t$, defined by the function $\tilde{p}(S_t)$ in (2), where S_t is the stock of gold remaining at time t conditional on the price-fixing scheme remaining in effect until that date:

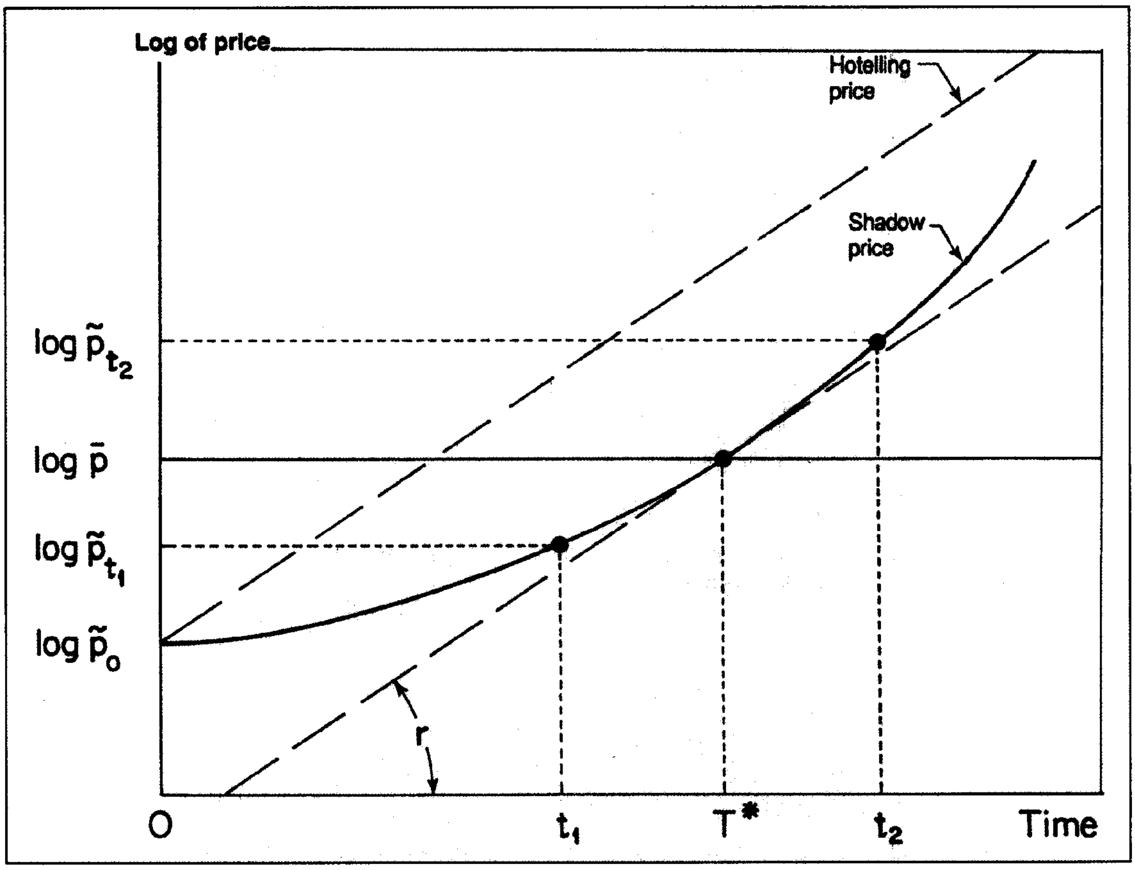
$$(3) \qquad \tilde{p}_t = (r\sigma S_t)^{-1/\sigma} = \{r\sigma[S_0 - D(\bar{p})t]\}^{-1/\sigma}.$$

(1) Monetary models of gold standards, which combine the natural resource aspect of gold with its monetary function, are analyzed by Flood and Garber (1984a), Bordo and Ellson (1985), and Barsky and Summers (1988). Here I do not mean my identification of the resource with gold to be taken too literally.

(2) In more general models, price must rise at a rate of r less marginal extraction cost. That more general condition allows gold in the ground to coexist with, say, gold jewelry that yields a utility flow. With zero extraction cost, allowing a utility value from holding gold above ground would lead to the immediate extraction of all gold and a rate of price increase somewhat below r.

The price $\tilde{p}_t$ is interpreted as the shadow free-market price of gold given a price hypothetically fixed at $\bar{p}$ between dates 0 and t, but not after; it is the competitive market price that would prevail in the absence of future price fixing, given the economy's remaining stock of gold, $S_t = S_0 - D(\bar{p})t$, when the price has been fixed at $\bar{p}$ in the past.

Figure 1



When $\tilde{p}_t < \bar{p}$, $\tilde{p}_t$ is rising at a proportional rate below the real interest rate r because the economy is using gold more slowly than it would were $\tilde{p}_t$ the actual price. When $\tilde{p}_t > \bar{p}$, $\tilde{p}_t$ is rising at a proportional rate greater than r because gold is being consumer more quickly. Since $\dot{S}_t = -D(\bar{p}) = -(\bar{p})^{-\sigma}$ under price fixing, equation (3) discloses that

$$\frac{\dot{\tilde{p}}_t}{\tilde{p}_t} = r\left(\frac{\tilde{p}_t}{\bar{p}}\right)^{\sigma},$$

which confirms the intuitive argument just given (1).

The date T^* at which the two price lines intersect is the date on which the price-fixing scheme collapses; it does so after a speculative attack in which private market participants acquire all of the remaining official gold stock at price $\bar{p}$. Thereafter a *laissez-faire* equilibrium prevails, with market price rising at rate r until the (perhaps infinite) choke price is reached and the economy's gold stock is

(1) Notice in particular that $\tilde{p}_t \neq \tilde{p}(S_0)e^{rt}$, where the latter (shown by the upper dashed line in the figure) is the *laissez-faire* or *Hotelling* price prevailing (given an initial gold stock of S_0) if the government never intervenes in the gold market. In contrast, in the equilibrium under study now, demand is at $D(\bar{p})$ for dates t prior to the date of the crisis, not at $D[\tilde{p}(S_0)e^{rt}]$. Thus, S_t under the price-fixing-cum-collapse scenario generally won't equal the gold stock the economy would have had on date t had *laissez-faire* prevailed since date 0, even though the gold stock on date 0 was S_0 in both regimes.

exhausted (see the lower dashed line in figure 1). The episode of price fixing only postpones the date $\tilde{p}_t$ reaches p^c. In the case $D(p) = p^{-\sigma}$, $T^* = \bar{p}^{\sigma}S_0 - (1/r\sigma)$. ($T^* \leq 0$ implies an attack the moment price fixing is attempted.)

Why does the crisis occur precisely on date T^*? For dates t_1 earlier than T^*, there would be a sharp fall in the price of gold, from $\bar{p}$ to $\tilde{p}_{t_1}$, once the economy's gold stocks were again in private hands. The prospect of this loss would induce each individual speculator, and hence all of them, to refrain from buying gold from the government at price $\bar{p}$ on date t_1. For dates t_2 later than T^* an attack would force the market price of gold to jump upward, from $\bar{p}$ to $\tilde{p}_{t_2}$. The prospect of such an instantaneously infinite rate of capital gain would entice each speculator, and hence all of them, to buy as much gold as possible at the official price an instant before t_2. Thus, T^* is the exact date of the crisis. On that date, speculators purchase all gold held by the authorities but there is no discrete jump in gold's price[1].

1.2. The Foreign Exchange Market Analogy

To analyze the collapse of a fixed exchange rate in a model analogous to the foregoing resource model, imagine a monetary economy in which the demand for domestic (high-powered) money takes the form

$$(4) \qquad \frac{M_t}{P_t} = Ae^{-\eta i_t},$$

where A is a constant, P_t is the domestic money price level, and i_t is the domestic nominal interest rate. Under perfect asset substitution, capital mobility, and perfect foresight, the domestic nominal interest rate is linked to the (constant) foreign nominal rate i^* by the interest parity condition

$$(5) \qquad i_t = i^* + \dot{E}_t/E_t,$$

where E_t is the price of foreign currency in terms of domestic currency (the exchange rate) and $\dot{E}_t/E_t$ is the instantaneous expected (and actual) rate of change in that price. To make matters as simple as possible, let purchasing-power parity (PPP) link the domestic and foreign price levels. With the latter assumed constant and normalized at unity, PPP implies that we can identify the price level P_t with the exchange rate E_t (so that $P_t = E_t$ henceforth).

If the exchange rate is fixed at E, the central bank must stand ready to intervene in the money market so that domestic monetary conditions remain consistent with that rate. Write the central bank's balance sheet (ignoring net worth) as

$$(6) \qquad M_t = C_t + Ef_t,$$

where C_t is nominal domestic credit and f_t the stock of foreign-exchange reserves, valued in foreign currency. In principle, central-bank financial operations take the form of variations in C_t as well as in f_t; provided domestic and foreign-currency bonds are perfect substitutes (as is assumed in (5), and as is necessarily the case under a credibly fixed exchange rate), the two types of operation are equally efficient means of maintaining the exchange parity. Attack models *à la* Krugman (1979) assume, however, that the domestic-credit process in exogenous, meaning that the bank's reserves bear the full adjustment burden to balance-of-payments pressures. Specifically, the model assumes that domestic credit grows at a constant proportional rate $\gamma > 0$ regardless of events in the foreign exchange market:

$$(7) \qquad \frac{\dot{C}_t}{C_t} = \gamma.$$

The strong assumption (7) implies that official reserves will be declining through time while the exchange rate remains fixed; this ever-shrinking reserve stock is analogous to the declining resource stock in the Hotelling-Salant-Henderson model. As long as the exchange rate is fixed at E, expected

(1) Observe that for $t > T^*$, the competitive price p_t is below $\tilde{p}_t$ because the former price rises only at rate r once the collapse has taken place.

depreciation is zero and nominal money demand is, by (4), constant at $\overline{M} = EAe^{-\eta i^*}$. Thus $\dot{M} = \dot{C} + E\dot{f} = 0$, so if ω_f is the share of reserves in M,

$$(8) \qquad \frac{\dot{f}_t}{f_t} = -\frac{(1-\omega_f)}{\omega_f}\gamma < 0.$$

While a shrinking resource stock arises endogenously in the resource model, it is imposed exogenously, through (7), in this foreign-exchange case. The equilibrium of the model still involves a speculative attack provided there is some lower limit on foreign-exchange reserves. This lower limit is taken (arbitrarily) to be zero.

The resource model assumed that the government refrained from intervention after the collapse of the price-fixing scheme. This outcome is not inevitable; the government could reset the price at a new level above $\overline{p}$ and (temporarily) regain its stockpile (enriching speculators in the process). Such a move is analogous to a devaluation in the foreign-exchange setting (1). To keep to the analogy with the resource model, however, I assume that once foreign reserves touch their lower limit of zero, the authorities institute an indefinite float of the currency.

In the present context the analog of the resource shadow price is the shadow exchange rate, introduced by Flood and Garber (1984b). The shadow exchange rate $\tilde{E}_t$ is the floating rate that clears the foreign exchange market, given the stock of domestic credit C_t, after all foreign-exchange reserves have passed into private hands. Under perfect foresight the natural logarithm of that rate is (2)

$$(9) \qquad \log \tilde{E}_t = \eta(i^* + \gamma) + \log C_t.$$

Figure 2 shows how the fixed exchange rate collapses under these assumptions. Panel (a) graphs the shadow floating exchange rate (9) along with the pegged rate. The schedules' intersection determines the time T^* of the speculative attack. (The reasoning pinpointing the collapse of price fixing in the resource model applies here as well.) Panel (b) shows money-supply behavior along the economy's equilibrium path. Panel (c) shows the path of foreign reserves implied by (8) (3).

The key feature of the equilibrium is that reserves take a discrete jump to zero at T^*, rather than declining smoothly to zero at time $\hat{T}$. This drop in reserves is the result of a sudden attack in which market participants, taking advantage of the central bank's commitment to sell foreign exchange at the price E, strip it of its remaining reserves. A discrete jump in reserves is necessary to avoid a discrete jump in the exchange rate: because the expected rate of currency depreciation rises from 0 to γ at time T^* and i rises from i^* to $i^* + \gamma$, the money market can remain in equilibrium at the initial price level $P = E$ only if the nominal money supply falls enough exactly to accommodate the implied fall in real money demand.

Critical to the preceding result is an assumption that η, the interest-sensitivity of money demand, is positive. Otherwise expectations don't matter: if $\eta = 0$, foreign reserves hit zero only at time $\hat{T}$ because the transition to a float occasions no sharp fall in money demand. Obviously, the bigger is η the earlier the date of attack, other things equal.

This type of speculative-attack model was extended to a discrete-time environment with stochastic domestic-credit growth by Flood and Garber (1984b) (4). In their model, domestic credit growth fluctuates randomly around a positive trend growth rate. Now T^* is a random variable rather than a perfectly foreseen date. Realistically, the stochastic model predicts that as reserves decline, the nominal interest rate rises as the probability increases that an unexpectedly large domestic-credit shock pushes reserves to zero and knocks out the exchange-rate peg. On the date the collapse occurs, the home currency suffers a discrete—albeit unanticipated—depreciation.

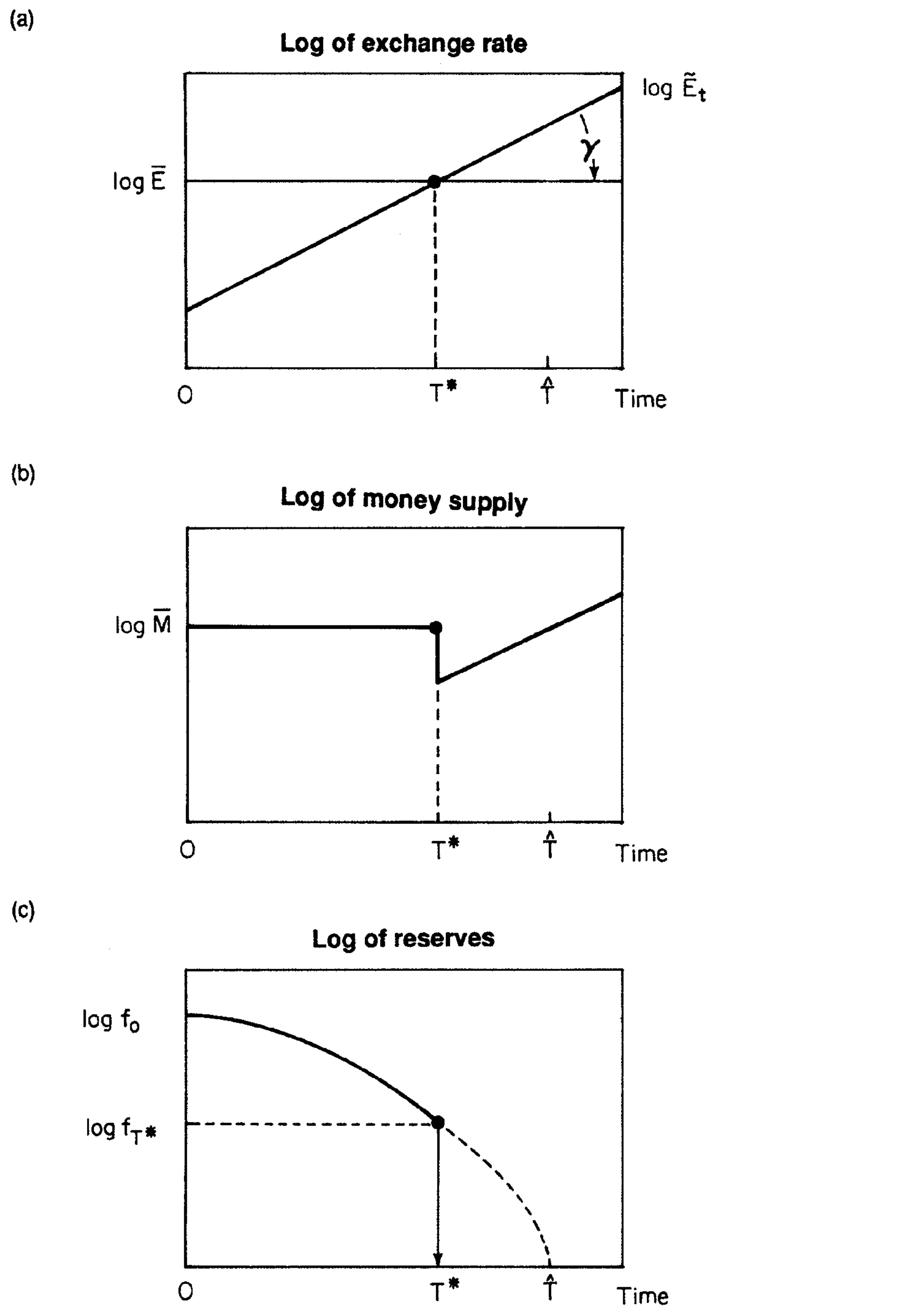
(1) If resource speculators anticipate with certainty that an attack will set off a discrete rise in $\overline{p}$, however, the only equilibrium is an immediate attack. Similarly, if foreign-exchange speculators expect an attack to cause a devaluation with certainty, they strike immediately and reap the gains. If the price changes occur only after a transitional period of floating, then an attack may not take place right away.

(2) This solution is based on the normalization $A = 1$.

(3) The vertical scales in panels (b) and (c) are not intended to be the same.

(4) Goldberg (1991) has added additional stochastic elements to produce a richer account.

Figure 2


(a)
Log of exchange rate
log $\tilde{E}_t$
γ
log $\bar{E}$
O
T*
$\hat{T}$
Time
(b)
Log of money supply
log $\bar{M}$
O
T*
$\hat{T}$
Time
(c)
Log of reserves
log f_0
log f_{T*}
O
T*
$\hat{T}$
Time

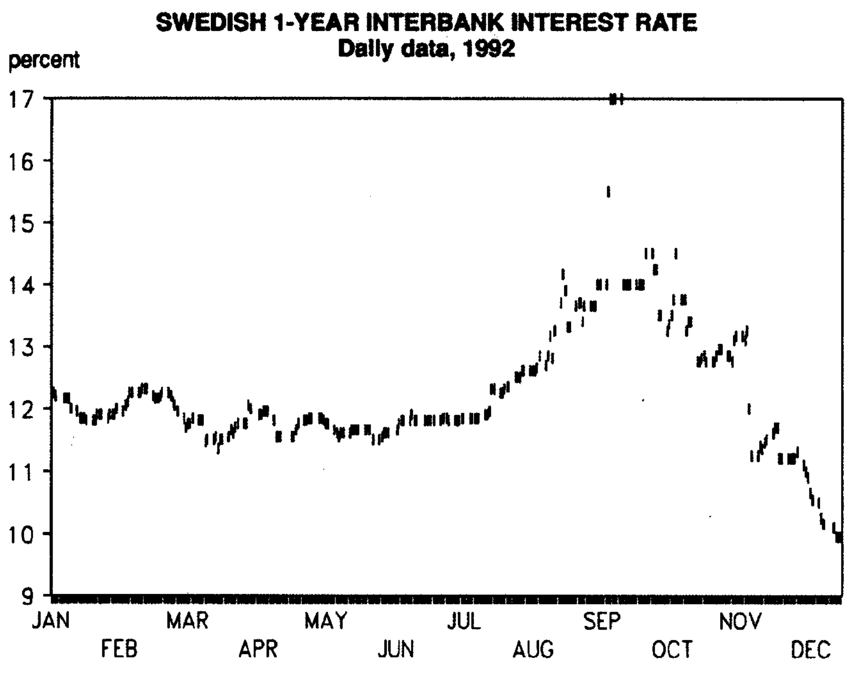
1.3. Evaluation

Models in the spirit of Krugman (1979) provide elegant parables of how rational financial markets respond to unsustainable macroeconomic policies. The models ignore, however, the policy options available to authorities and the ways in which the marginal costs of exercising these options are balanced. Since the actions of rational speculators must be conditioned on the conjectured response of the authorities, the class of models reviewed gives relatively little general guidance on the factors generating crises and determining their outcomes.

Some interesting recent models have offered explicit political underpinnings for models such as Krugman's. Guidotti and Végh (1992) develop a model in which a "war of attrition" over balancing the national budget leads to continuing finance through reserve drains; if agreement is not reached in time, a crisis can occur. Velasco (1993) considers a scenario with divided government in which reserve drains occur because individual ministries fail to internalize the overall public-sector constraint. Stein and Streb (1993) propose an asymmetric-information model in which governments may rationally run down foreign reserves so as to push inflation into the future, thus risking a crisis later. These papers yield important insights into the genesis of crises in countries where fiscal profligacy is the sole underlying cause of currency instability, but they do not cover the entire range of factors at work, particularly in the European context.

Consider, for example, the travails of the Swedish krona during 1992 (1). Sweden announced a unilateral peg to the European Currency Unit in May 1991. The Danish rejection of the Maastricht Treaty on June 2, 1992 was the occasion for a small immediate rise in krona interest rates; these rates rose sharply as uncertainties intensified over the summer (figure 3). The culmination of these developments was an attack on non-EC Nordic currencies in late August and early September, during which Swedish interest rates rose to unprecedented levels. While the krona peg survived this battle, it lost the war soon after, succumbing to a new attack on November 19 and entering a float.

Figure 3



(1) Hörngren and Lindberg (1993) present an excellent review of recent Swedish currency experience.

Figure 4, which graphs 1992 data on the Sveriges Riksbank's foreign exchange reserves [panel(a)] and net forward position in foreign currencies [panel (b)], reflects a story quite different from that behind panel (c) of figure 2 (1). Sweden's foreign exchange reserves were trendless (or slightly increasing) through early June, dropping only slightly by early August. There was virtually no net central-bank forward intervention in this period. Starting July 24, the Riksbank began to raise the marginal interest rate it charges the domestic banks.

At the height of the August-September attack the Riksbank intervened heavily in the krona's defense, borrowing reserves for this purpose in the second week of September. The resulting reserve shifts are apparent in figure 4. Most intervention took the form of spot foreign-currency sales, although the Riksbank also intervened in the forward market. After the initial storm had passed, however, total central-bank assets rose, interest rates fell, and reserves rose—until, quite suddenly, the ECU peg collapsed in mid-November.

A model to illuminate these events must encompass many more variables than simply the level of Sweden's foreign exchange reserves. Sweden was in recession in the summer of 1992; its unemployment rate jumped sharply from a 1982-91 average of 2.4 percent to 5.3 percent over all of the following year. In addition, the government's budget deficit had recently surged from an average surplus of 2.5 percent of GDP over 1987-91 to a deficit of 7.1 percent of GDP in 1992. Nonetheless, the legislature seemed far from agreement on a deficit reduction package. A troubled domestic banking system, unable to tolerate high interest rates, was straining the public finances. Finally, the krona had appreciated sharply in real terms since the end of 1990, and Sweden's switch from a trade-weighted basket peg to an ECU peg in the spring of 1991 made it more vulnerable to the dollar's depreciation over 1992.

In these circumstances, Sweden's maintenance of the krona's ECU peg was possible only at the cost of considerable short-term pain; and the conservative government naturally found its popularity falling. The perceived benefits from holding on were twofold. First, even though inflationary pressures were, for the moment, at bay, the government believed its long-term credibility would be damaged by a retreat from its announced nominal-anchor rule. Second, Sweden wished to demonstrate its readiness for EC membership by successfully pegging to the ECU—a strategy also followed by Norway and Finland.

This second motivation was crucial, for it implied that any event that made devaluation more "excusable" in the eyes of EC members, or that lessened the expected benefits of EC membership, would shake the government's resolve to tolerate further pain. The Danish vote, which made European unification look less likely for the near term, was the first shock: it signaled that the costs of abandoning an ECU peg, not only for Sweden, but for *de jure* Exchange Rate Mechanism members, might turn out lower than previously reckoned. To counter these impressions and restore stabilizing expectations France, on June 3, announced a September 20 referendum on the Maastricht Treaty. But this tactic soon backfired as French public opinion shifted against Maastricht.

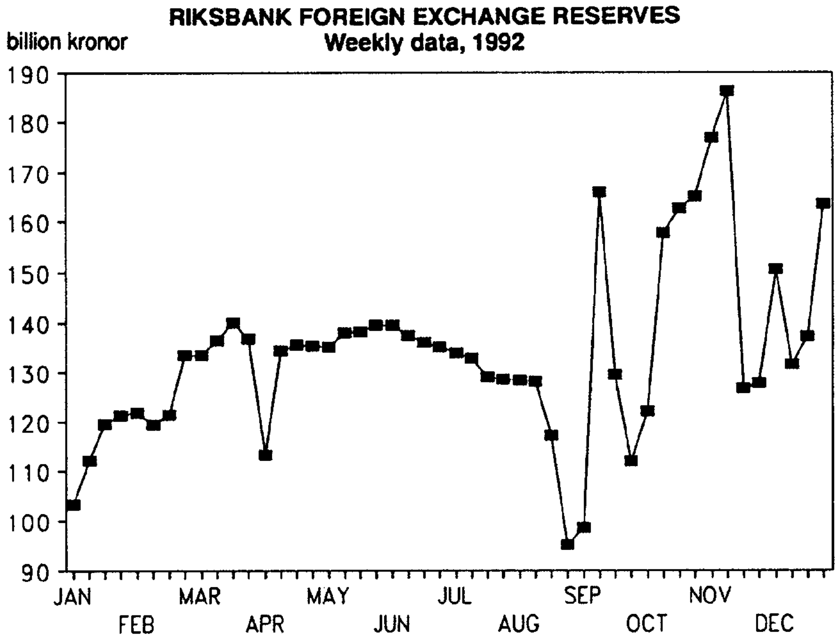
Finland, which had devalued last at the end of 1991, was the first country to come under pressure. Once the markka was floated on September 8, Sweden's resolve was put to the test and its fierce, and temporarily successful, defense of the krona began in earnest; by September 16 the Riksbank had been forced to increase its overnight lending rate to 500 percent per annum, an act that placed strain on private-sector balance sheets as well as on the government's. After a subsequent political agreement to cut public expenditure, the foreign-exchange market stabilized and the Riksbank began to lower interest rates and regain foreign reserves. The central bank simultaneously increased its exposure in the forward market, perhaps to signal its resolve.

Surprisingly, in light of their painful struggle with the markets only two months earlier, the Swedish authorities floated the krona on November 19 without an aggressive interest-rate defense like the one in September. Instead, the response to renewed speculation was a strategy of limited

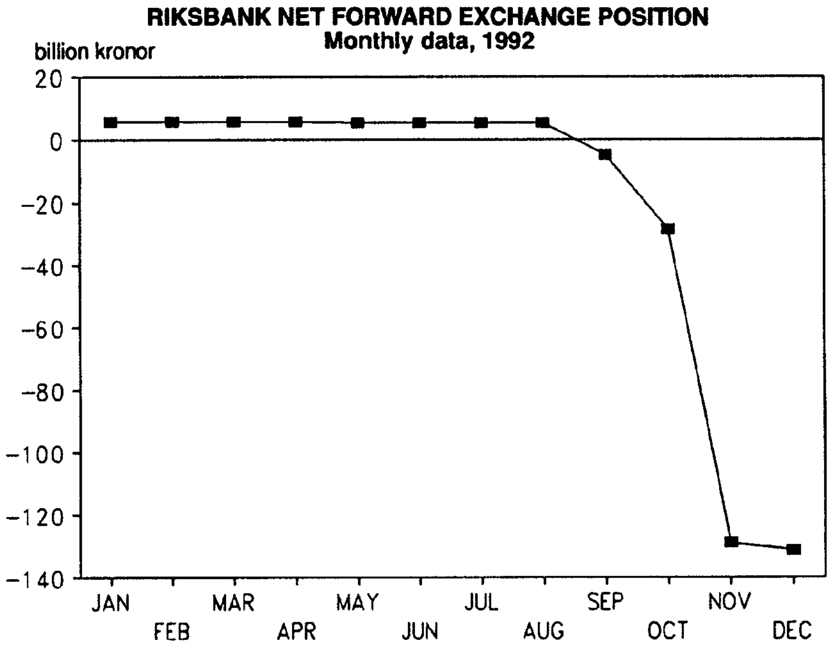
(1) Reserve data come from the *Riksbank's Assets and Liabilities: Weekly Statement*, various issues. Forward position data are reported in the *Riksbank's Quarterly Review*, 1993:4, table 28; they do not appear on the bank's balance sheet. Note that an official forward sale of foreign currency effectively reduces the net supply of domestic-currency bonds in private hands while increasing that of foreign-currency bonds; there are no monetary-base effects. The forward sale thus is equivalent to a sterilized spot sale of foreign reserves. Forward positions can be rolled over upon maturity through a swap of domestic for foreign currency.

Figure 4

(a)


RIKSBANK FOREIGN EXCHANGE RESERVES
Weekly data, 1992
billion kronor
190
180
170
160
150
140
130
120
110
100
90
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

(b)


RIKSBANK NET FORWARD EXCHANGE POSITION
Monthly data, 1992
billion kronor
20
0
-20
-40
-60
-80
-100
-120
-140
JAN
FEB
MAR
APR
MAY
JUN
JUL
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interest-rate increases and mostly sterilized intervention, a strategy that led to massive reserve losses (see the two panels of figure 4)(1). But these losses were a symptom, and not the cause, of the krona peg's political and economic unsustainability(2).

What explains the Swedish government's surrender? Economic pain has a cumulative effect: the government had taken all it could during the August-September crisis and had little stomach for more. Furthermore, the indefinite exit of England and Italy from the ERM on "Black Wednesday", September 16, coupled with the Spanish devaluation, left Sweden with little more to prove concerning its convergence to EC policies. These events and the French *petit oui* on Maastricht left the future of the EMS itself in doubt.

What lessons does the Swedish example teach? In general governments have several options that can be exercised in defense of an exchange parity, including borrowing foreign reserves, raising interest rates, reducing government borrowing requirements and, as was the case for some ERM members, tightening or imposing exchange controls. These strategies, if followed to the limit, have some chance of success. But they are painful, especially when unemployment is high and the public and private sectors are acutely vulnerable to high *ex post* real rates of interest. Governments therefore will balance the costs of such defenses against the benefit of resisting realignment pressures; and often they will conclude that the pain is not worth the gain. Any economic event that raises the market's estimation of the government's susceptibility to pain, or that lowers the perceived gains from a successful parity defense, can trigger a speculative attack. There need be no long prologue to such an attack; market sentiment can shift almost overnight. Table 1 illustrates how little markets anticipated the autumn 1992 crisis by showing the losses a German investor in some devaluing currencies would have made by rolling over one-month deposits from the announcement or tightening of an ECU peg through the month of collapse.

Table 1

RETURN, IN DEUTSCHEMARKS, ON COMPOUNDED ONE-MONTH DEPOSITS OF OTHER EUROPEAN CURRENCIES

(annualized percent rates)

Currency	Dates of Investment	Return	Comparable Return on DEM
Lira	January 1990-October 1992	6.42	9.22
Krona	June 1991-December 1992	– 0.12	9.73
Pound sterling	October 1990-October 1992	1.67	9.56

Source: DRI data.

If governments determine the extend of their resistance through a cost-benefit analysis, however, self-fulfilling crises become likely in situations where economic distress already places the government under pressure. The reason is that the cost of resisting an attack depends in part on endogenous variables. If markets expect devaluation, for example, domestic interest rates will rise, thus creating an incentive to devalue. Similarly, expectations of devaluation may be incorporated in wage demands, raising authorities' incentive to accommodate. These processes are circular: thus their timing is basically arbitrary and they can be bought into play by seemingly minor events.

(1) Hörngren and Lindberg recount that the Riksbank sold over 160 billion kronor in six days. The kronor magnitudes in figure 4 have not been revalued to reflect the currency's depreciation starting on November 19.

(2) Figure 4 gives the impression that the sum of the Riksbank's foreign reserves and net forward position was around zero when the krona collapsed in November—an apparent confirmation of Krugman's (1979) assumption that total reserves are driven to zero in a collapse. This appearance is an artifact of intra-government accounting conventions. Offsetting the Riksbank's large foreign reserve acquisition in early September [panel (a)] was a corresponding balance-sheet liability to Sweden's National Debt Office, which itself borrowed intervention reserves for the Riksbank in the foreign exchange market. The resulting "domestic" liability on the Riksbank's balance sheet thus reflected a foreign liability of the Swedish government. Arguably, Sweden's foreign reserves were below zero at the end of November 1992.

2. MARKET FORCES AND GOVERNMENT INCENTIVES IN CRISES

This section explores economic two models of self-fulfilling crisis that highlight the government's endogenous response to market expectations. In the first, devaluation expectations feed into interest rates and thus can sap the government's resolve to resist a validating realignment. In the second, expectations feed into wages and competitiveness, creating similar incentives by raising unemployment.

While the first model shows how strategic exchange intervention may alter the likelihood and severity of a crisis, both models assume that foreign reserves can be freely borrowed in the world capital market, subject only to the government's consolidated intertemporal budget constraint. Neither model assumes additional reserve constraints, nor assigns to reserve levels *per se* a special role in generating balance-of-payments crises.

2.1. The Role of Nominal Interest Rates

A factor often cited in explaining why a government accedes to devaluation pressures is the increased cost of servicing the public debt. Ultimately, accounts of crises based on limited foreign reserves must also be based on overall fiscal weakness: were the public fiscal position robust, it would be credible and feasible to borrow sufficient reserves to repurchase a large portion of the high-powered money supply and thereby fend off any attack. The model of this section extends the insightful contribution of Giavazzi and Pagano (1990) by modeling the intertemporal decisions of an explicity purposeful government (1). Two factors that turn out to play a key role in affecting the likelihood of crises are the maturity structure of the government's domestic obligations (as in the Giavazzi-Pagano analysis) and the currency composition of the overall public debt (2).

The world lasts for two periods, labeled 1 and 2. I will consider the position of a government that issues a domestic currency unit (called the "lira") but also participates in the market for a foreign currency (the "mark"). The government enters period 1 with obligations to pay to claimants the nonnegative amounts ${}_0D_1$ lire in period 1 and ${}_0D_2$ lire in period 2. In parallel notation, the government enters period 1 entitled to receive payments of ${}_0f_1$ marks in period 1 and ${}_0f_2$ marks in period 2. The levels of real government consumption in the two periods, g_1 and g_2, are given exogenously. Finally, the government can levy taxes on output at rate τ to balance its budget, but only in period 2.

The pair $\{{}_0D_1, {}_0D_2\}$ defines the maturity structure of the government's lira debt—its intertemporal endowment of domestic-currency liabilities. When ${}_0D_1 = 0$ any government debt is long-term, but when ${}_0D_2 = 0$ any government debt is short term and must be rolled over in period 1. This, as shown below, is a potential source of difficulties for a government that lacks credibility.

The assumptions of PPP and $E = P$ are retained from the last section. In period 1 lira/mark exchange rate is fixed at E_1, but in period 2 the rate may be changed to E_2. The letter i denotes the nominal interest rate on loans made in period 1 and repaid in period 2.

Public-sector "cash-flow" constraints (3) reveal how the government's maturity and currency exposure change its vulnerability to market developments. Denote by ${}_1D_2$ new lira obligations due in period 2 that are incurred by the government in period 1. The **period 1** constraint is

$$(10) \qquad {}_1D_2 = (1 + i)\left[{}_0D_1 + E_1g_1 - E_1({}_0f_1) + \frac{E_1({}_1f_2)}{1 + i^*}\right].$$

(1) The model develops ideas sketched Obstfeld (1990a). Giavazzi and Pagano, as I do here, built on Calvo's (1988) important analysis of dual equilibria in markets for domestic-currency public debt. (See also Alesina, Prati, and Tabellini 1990.)

(2) Formal models of government behavior incorporating these factors were introduced by Lucas and Stokey (1983), Persson and Svensson (1994), and Persson, Persson, and Svensson (1987). Milesi-Ferretti (1993) explores political motivations for debt management in a monetary model.

(3) The terminology comes from Persson and Svensson (1984).

In (10), ${}_1f_2$ signifies the new mark-denominated claims due in period 2 that the government acquires in period 1 (including new central-bank foreign exchange reserves). In words, (10) implies that in period 2 the government will subtract from its original lira cash flow the principal and interest on its period 1 lira borrowing. The latter, in turn, equals lira debt service, government consumption expenditure, and the acquisition of new mark assets, less mark receipts that accrue in period 1. The government's only choice in period 1 (given the assumed setup) is the currency composition of borrowing.

What is the government's position in period 2? It must meet all period 2 obligations, whether incurred in period 1 or before, and spend E_2g_2 lire besides. The revenue to finance these obligations comes from mark assets, taxes on domestic output y, and any increase in the amount of (high-powered) money residents wish to hold in period 2, M_2, over the amount held in period 1, M_1 (1). The implied **period 2** constraint is (2):

$$(11) \qquad {}_1D_2 + {}_0D_2 - E_2({}_1f_2 + {}_0f_2) + E_2g_2 = E_2\tau y + M_2 - M_1.$$

Under the assumptions of capital mobility and uncovered interest-rate parity, perfect-foresight equilibrium entails the *ex post* equality of lira- and mark-asset returns, measured in lire,

$$(12) \qquad 1 + i = (E_2/E_1)(1 + i^*).$$

Given (12), (10) and (11) may be combined to yield the familiar intertemporal government budget constraint (expressed in lira terms),

$$(13) \qquad E_1({}_0f_1) - {}_0D_1 + \frac{E_2({}_0f_2) - {}_0D_2}{1 + i} = E_1g_1 + \frac{E_2g_2 - \tau y - (M_2 - M_1).}{1 + i}$$

Private money demand obeys the simple quantity equation:

$$(14) \qquad M_t = kE_ty \quad (t = 1, 2),$$

where real output is assumed constant. Incorporating a nonzero nominal interest elasticity of money demand would add nothing to this model, despite its centrality in models of the Krugman (1979) variety, so equation (14) is adopted to simplify the algebraic analysis (3). Note the unrealistic assumption that the public holds money in period 2 even though that period is the economy's last and agents could raise consumption by spending it all. This situation arises in certain models of money demand (for example, Brock 1975), but different assumptions about the disposition of period 2 real balances could be made without altering the model's main thrust.

Consider next the government's position. The government cares only about the distorting effects of (*ex post*) inflation and the tax rate. Since both of these variables are, by assumption, zero in period 1, the objective function the government minimizes can be written as

$$(15) \qquad \pounds = \frac{1}{2}\tau^2 + \frac{\theta}{2}\varepsilon^2,$$

where ε is the lira's depreciation rate against the mark (the inflation rate of lira prices) between periods 2 and 1,

$$(16) \qquad \varepsilon = (E_2 - E_1)/E_2,$$

and $\theta > 0$ measures the weight placed on depreciation relative to other taxes. The simple quadratic specification in (15) is chosen for simplicity only. There is nothing in (15) to capture the notion that a realignment *per se*, even if small, can cause the government permanently to lose credibility or face. Such an additional, fixed, cost of realignment alters the analysis substantially, as is shown later, but it is easier to see why once the implications of the simpler loss function (15) have been laid out.

(1) The tacit assumption in (10) is that no seigniorage revenue is available in period 1 because the exchange rate must remain fixed until period 2.

(2) In (11) below, it would be more appropriate to take private-sector income as the tax base, but this would only introduce inessential complications. Notice, however, that since y excludes interest payments on government debt held by the domestic public, a tax rate τ on y in excess of 1 is not excluded.

(3) Adding a traditional interest-rate response of money demand would only raise the likelihood of the multiple equilibria shown below.

In analyzing the government's behavior it is convenient to translate (10) and (11) into forms that clarify the fiscal role of the depreciation rate ε. Let the symbol $_td_s$ denote the real value at the period 1 price level of the lira government debt payment promised on date t for date $s > t$. Then (11) and (10) translate into

$$(17) \qquad \varepsilon\,({}_1d_2 + {}_0d_2 + ky) + \tau y = {}_1d_2 + {}_0d_2 + g_2 - {}_1f_2 - {}_0f_2,$$

where

$$(18) \qquad {}_1d_2 = (1+i)\left({}_0d_1 + g_1 - {}_0f_1 + \frac{{}_1f_2}{1+i^*}\right).$$

Equation (17) states that on date 2 the proceeds of the inflation levy plus conventional taxes must suffice to repay the government's net debt and pay for current spending. (Of course, $_1d_2 + {}_0d_2 + ky$ is the total inflation-tax base.)

In period 2 the government chooses ε and τ to minimize (15) subject to (17). Importantly, all variables in (17) other than ε and τ are predetermined when the government makes its choices in period 2. In particular, the interest rate i that prevailed in period 1, as well as the government's mark purchases then ($_1f_2$), are past history. If the government could precommit its period 2 actions in period 1, the government's choice problem would look quite different and the possibility of multiple equilibria would not arise: under precommitment the government would minimize (15) subject to (12)-(14), in effect choosing the interest rate between dates 1 and 2. The assumption here, instead, is that when period 2 comes the government does whatever minimizes (15) given the budgetary situation inherited from the past. The private sector has rational expectations about the government's objectives, and the forecast of lira depreciation incorporated in the nominal interest rate i is based on the assumption that the government will behave in this way.

Minimization of (15) subject to (17) requires the critical necessary condition:

$$(19) \qquad \frac{\theta\varepsilon}{({}_1d_2 + {}_0d_2 + ky)} = \frac{\tau}{y}.$$

Equation (19) states that at an optimum, the marginal cost of extra depreciation per lira raised equals the marginal cost per lira of higher conventional taxes. Using (19) to eliminate τ from (17) gives ε as

$$(20) \qquad \varepsilon = \frac{({}_1d_2 + {}_0d_2 + ky)\,({}_1d_2 + {}_0d_2 + g_2 - {}_1f_2 - {}_0f_2)}{({}_1d_2 + {}_0d_2 + ky)^2 + \theta y^2}.$$

Use of (18) to substitute for $_1d_2$ above shows how the government's preferred depreciation rate is affected by the market interest rate prevailing in period 1 and by the currency composition the government chooses for its debt then.

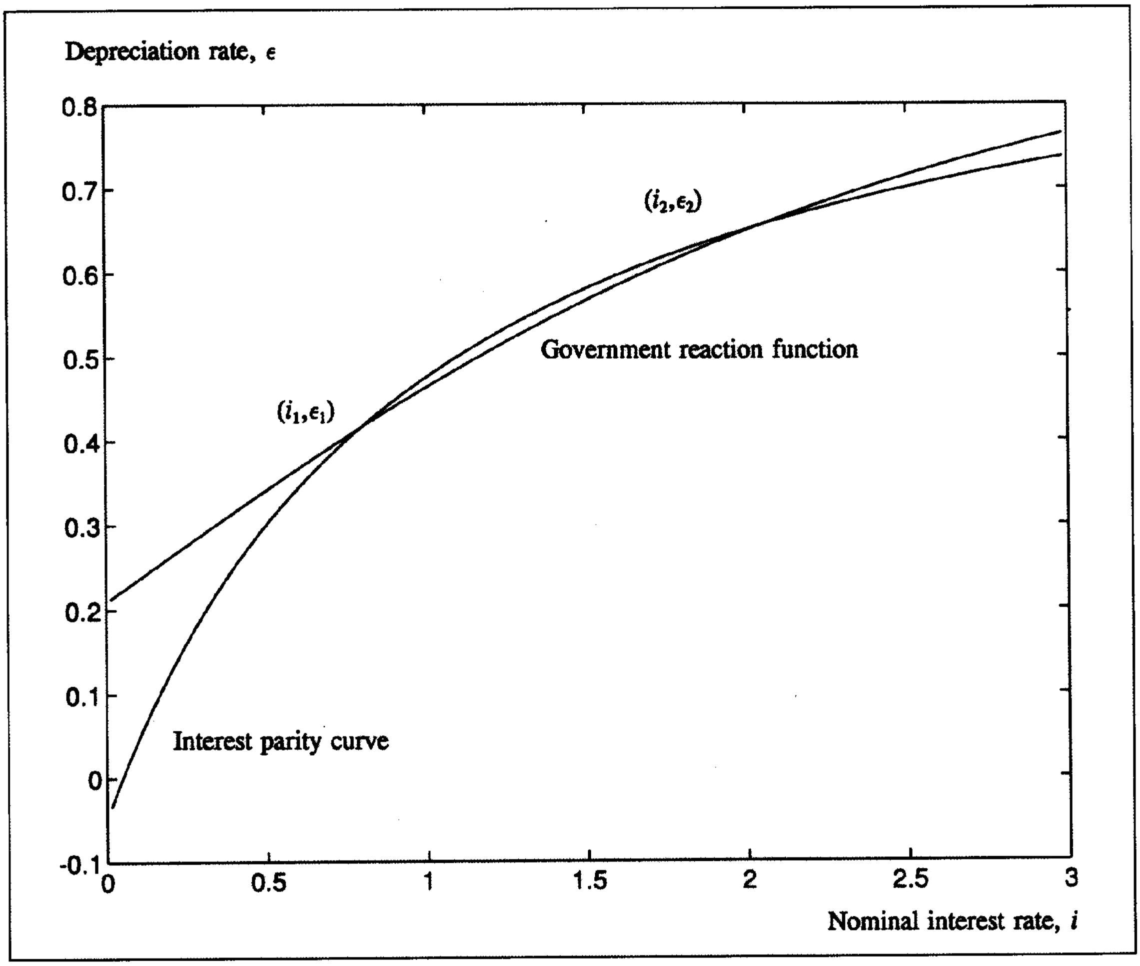
Figure 5 graphs two schedules that together determine the set of equilibrium period 1 nominal interest rates. The first is the depreciation reaction function of the government, that is, which shows the depreciation rate ε it chooses in period 2 when confronted with a lira interest rate of i. As noted above, this rate can be found by using (18) to eliminate $_1d_2$ from (20). I have assumed that the reaction function is positively sloped, although this depends on the government's fiscal position. Intuitively, the positive slope of the reaction function reflects the possibility that a higher period 1 nominal interest rate, by raising the inflation tax base in period 2, makes greater currency depreciation optimal then. For the moment, the quantity $_1f_2$, equal to period 1 official acquisition of mark assets, is taken as given. Its role, which clarifies the factors that lend a positive slope to the reaction function, is explored later.

The second upward-sloping schedule in figure 5, the interest parity curve, shows the expected rate of depreciation ε consistent with the lira interest rate i prevailing in period 1. Equations (12) and (16) show the equation for this schedule is

$$\varepsilon = \frac{i - i^*}{1+i},$$

which can be viewed as the reaction function of the lira bond market, that is, the interest rate it sets based on its expectation of ε.

Figure 5



In a perfect-foresight equilibrium, the depreciation rate the market expects must equal the depreciation rate the government finds optimal, given market expectations. Thus, intersections of the government reaction function and the interest parity curve determine possible equilibria of nominal interest rates and currency depreciation. Figure 5 shows a case in which this equilibrium is not unique. Notice that the inflation and interest rates illustrated in the figure seem implausibly high, but remember that this is a two-period model in which the government must repay its entire debt on date 2.

In figure 5 there are two equilibria (1). Obviously the government's loss is lower in the low-depreciation equilibrium, but there is no way to ensure that the bond market coordinates on the relatively low lira interest rate. The government faces a dynamic inconsistency problem: much as it would like to, it cannot credibly promise not to validate expectations if the bond market settles on the high-inflation equilibrium's interest rate.

Next consider the implications of this analysis for a regime of fixed exchange rates. International exchange rates are never irrevocably fixed. A sovereign government always can abandon a currency peg if economic conditions warrant a realignment. Assume, however, that the government faces a fixed cost c of realigning—a cost that could reflect political embarrassment and lost credibility, among other factors (2). In this case the loss function is

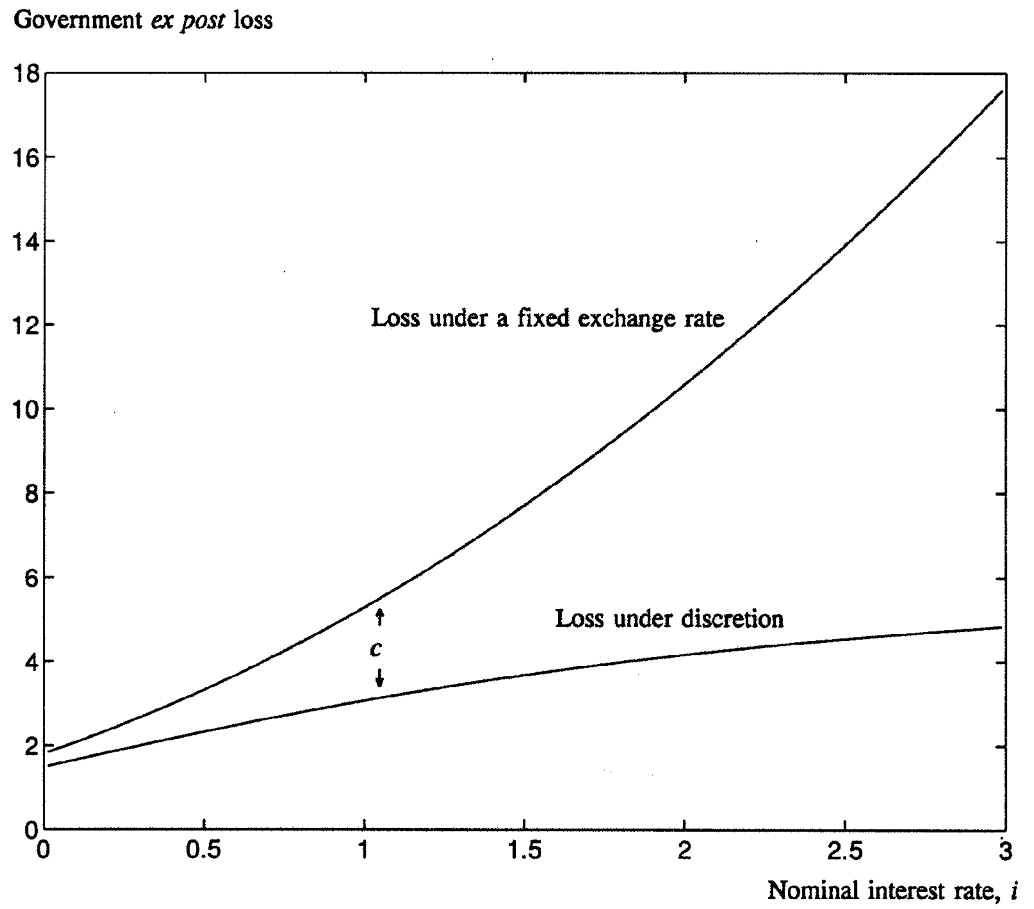
(1) It is obtained by setting $y = 1$, ${}_0d_1 = 1.0$, ${}_0d_2 = 0.2$, ${}_0f_1 = 0$, ${}_0f_2 = 0$, ${}_1f_2 = 0$, $g_1 = g_2 = 0.35$, and $i^* = 0.05$.

(2) De Kock and Grilli (1993) formalize the credibility costs of realigning through a trigger-strategy model. They also find a possibility of multiple equilibria. I do not take explore in detail why policymakers found it optimal to institute the fixed rate and subject themselves to the realignment cost. Particularly if we ignore the possibility of strategic debt management (taken up below), it is entirely possible that a realignment cost has the potential to improve economic welfare by preventing excessive currency depreciation.

$$(21) \qquad \pounds = \frac{1}{2}\tau^2 + \frac{\theta}{2}\varepsilon^2 + cZ \quad (Z = 1 \text{ if } \varepsilon \neq 0, Z = 0 \text{ otherwise}),$$

rather than (15). In figure 6 I have calculated how the original loss function (15) rises with the nominal interest rate under the purely discretionary regime analyzed so far, in which ε is given by (20), and under a fixed exchange rate, in which ε is constrained to be 0. (The parameter settings are the same as in figure 5.) Given the expectations embodied in the period 1 interest rate i, the loss under discretion is below that under a fixed rate, and the relative disadvantage of maintaining a fixed rate rises with i. Once the excess loss of a fixed exchange rate exceeds c, the government will find it optimal to devalue. The figure shows a value of c such that two distinct outcomes are possible. The first is that the bond market expects no devaluation, in which case the nominal interest rate is set at i^* and, indeed, no devaluation occurs.

Figure 6



The second possibility is a direct consequence of the existence of two equilibria under pure discretion. Suppose the market expects the currency to be devalued at the rate ε_2 shown in figure 5, and sets the nominal interest rate at the corresponding level i_2. Then the government will be induced to carry out the anticipated devaluation, the realignment cost c notwithstanding. This is a first example of a self-fulfilling speculative attack: there exists an equilibrium in which the exchange parity is viable, but the government is nonetheless led to change the parity simply because private expectations of a change make it too costly not to. Clearly, a sharp fall in c from a previously high level—as may have occurred, for example, after the Danish vote on Maastricht in the summer of 1992—could allow a devaluation equilibrium to emerge where none existed before.

Equations (18) and (20) show that the lira interest rate i enters the government's period 2 reaction function only *via* ${}_1d_2$, the new debt incurred in period 1; this new debt would in turn be absent [see (18)] if the condition

$$(22) \qquad {}_0d_1 + g_1 - {}_0f_1 + \frac{{}_1f_2}{1 + i^*} = 0$$

held true—that is, if the government had a zero total cash flow on date 1. (If equality (22) holds, the government reaction function in figure 5 is horizontal.)

Abstract for the moment from mark assets and liabilities. Then the government will have no reason to fear self-fulfilling devaluation expectations if ${}_0d_1 + g_1 = 0$, that is, if no domestic-currency debt needs to be issued or rolled over in period 1. The government will be closer to this happy state, as Giavazzi and Pagano (1990) stress, if ${}_0d_1 = 0$, so that all the government's debt is long-term. But, as explained in Obstfeld (1990a), this is not enough: debt management should try to match total short-term expenditure commitments to net short-term cash receipts, including repayment of principal (and, in general though not in this model, tax receipts) (1).

So far little has been said about reserve losses, which are at center stage in Krugman's (1979) story. Indeed, the assumption of interest-inelastic money demand in equation (14) means that period 1 expectations do not influence international reserves—a highly unrealistic feature of the model which, if relaxed, would only make self-fulfilling attacks more likely. Nonetheless, international reserves—more generally, any government positions in foreign currencies—can play a strategic role in the model. This point is seen by abandoning the temporary assumption that the foreign-asset terms in (22) are zero (2).

In principle, the option of official mark borrowing can eliminate the possibility of multiple equilibria even when the government has a substantially negative lira cash flow on date 1. As (22) shows, any foreign-currency receipts (principal or interest) due in period 1 will mitigate cash-flow needs then. But by setting ${}_1f_2/(1 + i^*) = -({}_0d_1 + g_1 - {}_0f_1)$, that is, by borrowing enough marks to entirely cover payments due, the government can sidestep the domestic band market altogether and thus head off a domestic funding crisis that could lead to devaluation (3).

This defensive foreign-currency borrowing would have to be huge if, as in the case of Italy, floating interest rates on public debt mean that most of it must effectively be refinanced each period. Some observers would judge such borrowing to be infeasible. Yet if the debt can be rolled over in domestic currency it should be possible to roll it over in foreign currency: in equilibrium the government faces the same intertemporal budget constraint under either choice.

While sufficient mark borrowing can remove the multiplicity problem in this model, and thus the possibility of a self-fulfilling attack on the lira, a small amount of foreign currency borrowing can make matters worse by lowering the depreciation tax base in period 2 but not radically reducing the government's incentive to devalue. Figure 7 shows how a relatively small amount of borrowing shifts the government reaction function downward but doesn't flatten it enough to avoid a high interest rate equilibrium worse than the original one (4). Foreign currency borrowing insufficient to eliminate a potential second equilibrium makes the government worse off if that potential is realized.

The model set out above captures aspects of the Italian crisis in September 1992, when the government was forced to rely heavily on Bank of Italy financing to cover sharply higher cash-flow

(1) This is not a balanced-budget prescription, since principal repayments are included in cash flow. Notice that if the government is exposed to the period 1 lira interest rate, there is always an asymptotic intersection at which $i = +\infty$ and $\varepsilon = 1$: the government's nominal commitments then are infinite and the only way to meet them is to eradicate their real value entirely through a confiscatory inflation. I don't consider this intersection at infinity to be an equilibrium.

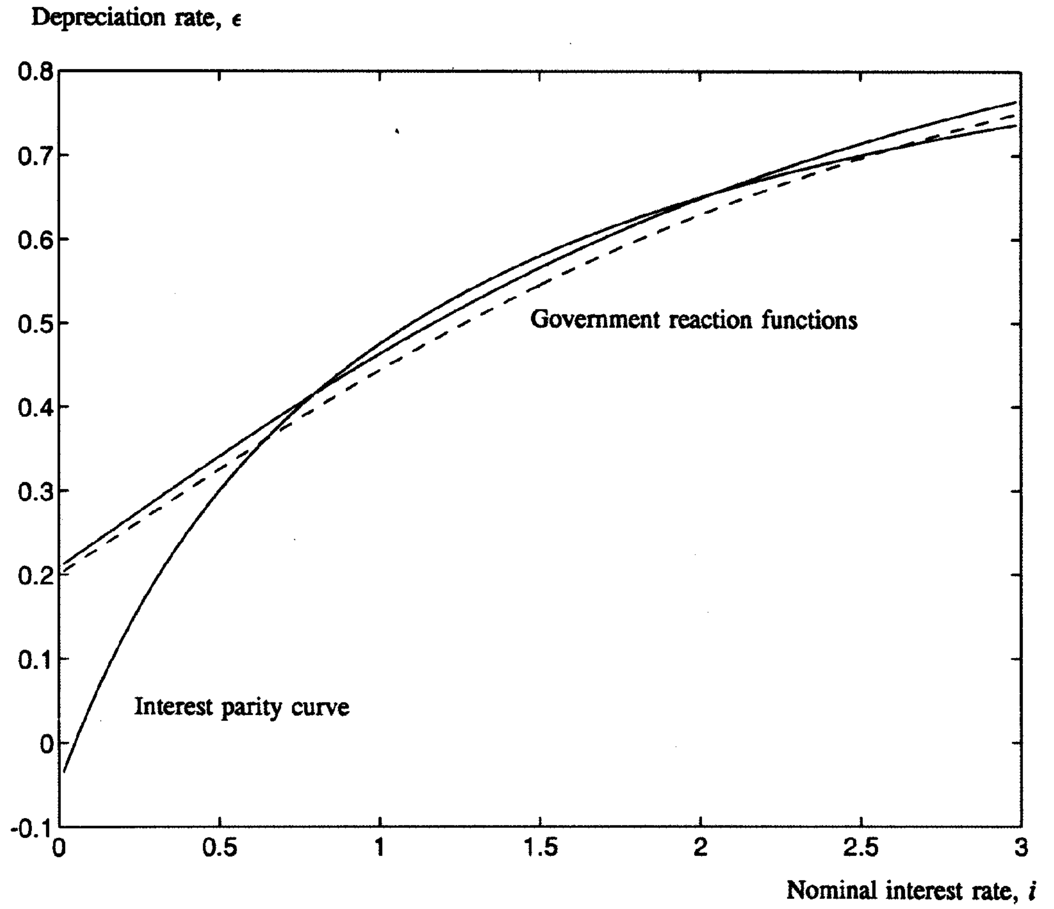
(2) In Obstfeld (1990b) I discuss this strategic role of reserve use in the context of sterilized foreign-exchange intervention. Calvo (1991) presents a model that illustrates a related point, that sterilization of reserve inflows in the course of inflation stabilization may raise inflationary expectations by increasing the outstanding stock of domestic-currency government debt.

(3) In essence, the government is issuing consumption-indexed debt in this case.

(4) The broken reaction function comes from keeping all the settings of figure 5 except that for ${}_1f_2$, which is lowered from 0 to – 0.25.

requirements. The model applies equally to other situations, such as Britain's in the 1950s and 1960s, when authorities sought to avoid the "twin disasters of internal and external collapse of the value of the pound sterling"[1] in the face of a large and increasing public debt.

Figure 7



2.2. The role of aggregate demand shocks

A second model, based on closed-economy models by Barro and Gordon (1983) and Kydland and Prescott (1977), shows that a regime of fixed but adjustable parities can engender multiple equilibria. In some equilibria the economy may be worse off than under irrevocably fixed exchange rates, as nominal wage-growth expectations erode competitiveness and make devaluations more frequent[2]. In this model devaluations are triggered by the government's desire to offset negative output shocks, but a sudden shift in market sentiment regarding the government's willingness to tolerate unemployment can trigger a devaluation that would not have occurred under different private expectations.

In this model, lower case variables denote natural logarithms and PPP holds, so that e, the (log) home-currency price of foreign exchange, equals p, the (log) money price of domestic output, given

(1) Goodhart (1973, p. 513).

(2) For a more detailed discussion of a similar model, see Obstfeld (1991).

that p^*, the (log) foreign-currency price level, is constant and normalized to zero. Domestic output y given by

$$(23) \qquad y_t = \alpha(e_t - w_t) - u_t,$$

where w is the money wage and u is a mean-zero, serially independent shock dependent on foreign interest rates, private and government demand shifts, and so on. Workers and firms agree to set period t wages w_t on date t-1 so as to maintain a constant real wage,

$$(24) \qquad w_t = E_{t-1}(e_t),$$

where $E_{t-1}(\cdot)$ is a conditional expectation based on date $t-1$ information. This information does not include u_t, and the wage is not indexed to the value of u_t that occurs.

While period t wages cannot adjust to period t demand shocks, the government can respond to them through changes in the contemporaneous exchange rate(1). This assumption gives stabilization policy a role. Assume temporarily, as in the last model, that the exchange rate can be freely managed and that the government's objective is to minimize the loss function

$$(25) \qquad \pounds_t = \sum_{s=t}^{\infty} \beta^{s-t}\ell_s = \sum_{s=t}^{\infty} \beta^{s-t}[\theta(e_s - e_{s-1}) + (y_s - y^*)^2],$$

where β, $0 < \beta < 1$, is the government's discount factor. (Later a fixed cost of realignment will be introduced.) The loss function (25) penalizes deviations of inflation rates from a target of zero. It also penalizes deviations of output from a target y^*. The target y^* could be 0, which happens to be the rational-expectations equilibrium output level when u is at its mean value of zero. I will assume, however, that the government targets a strictly positive y^*. Such targeting could reflect, for example, entrenched distortions in the labor market that lead to equilibrium output below the efficient level(2).

The government's flow loss for period t can be expressed as

$$(26) \qquad \ell_t = \frac{\theta}{2}(e_t - e_{t-1})^2 + \frac{1}{2}[\alpha(e_t - w_t) - u_t - y^*]^2.$$

with the help of (23). Under a regime with credible precommitment, the government would choose the path of the exchange rate once and for all in some initial period; this choice, in turn, would tie down expectations and the path of nominal wages. As in section 2.1, however, the model assumes that such precommitments aren't possible. Instead, the government chooses the home currency's exchange rate e_t each period to minimize ℓ_t given the nominal wages agreed in period $t-1$. (There is no intertemporal dimension to the government's exchange-rate decision, which does not affect the policy problem to be faced in later periods(3).)

Minimization of (26) over e_t (for given w_t) requires that

$$\frac{\partial \ell_t}{\partial e_t} = \theta(e_t - e_{t-1}) + \alpha[\alpha(e_t - w_t) - u_t - y^*] = 0.$$

Define λ to be $\alpha^2/(\theta + \alpha^2)$. Then the above derivative condition gives the government's reaction function:

$$(27) \qquad e_t - e_{t-1} = \lambda(u_t/\alpha) + \lambda(w_t - e_{t-1}) + \lambda(y^*/\alpha).$$

According to (27), the government uses the exchange rate partially to offset shocks u_t to output. Since wages were set in period $t-1$, however, the government also finds it optimal after the fact to attempt a "surprise" depreciation whenever wage inflation risks eroding competitiveness. Similarly, the government will attempt to drive output above its "natural" level by devaluing. Only as $\theta \to \infty$, so that

(1) I assume capital mobility and perfect asset substitution, so realignment is the only form monetary policy can take.

(2) Serial dependence in the employment shock u_t works like predictable time variation in y^*.

(3) This property would not hold if current government behavior influenced market expectations of its future behavior, as in the trigger-strategy equilibria analyzed by De Kock and Grilli (1993). Here, instead, market expectations are assumed to be history-independent.

inflation becomes infinitely undesirable, does a fixed exchange rate become optimal *ex post* ($\lambda \rightarrow 0$)(1). In general, λ measures the government's willingness to accommodate.

Of course, workers and firms understand the strategy in (27) and set wages accordingly. Equation (24) therefore implies that in a rational-expectations equilibrium

$$w_t = e_{t-1} + \lambda E_{t-1}(u_t/\alpha) + \lambda(w_t - e_{t-1}) + \lambda(y^*/\alpha),$$

or, since $E_{t-1}(u_t) = 0$,

$$(28) \qquad w_t = e_{t-1} + \frac{\lambda}{1-\lambda}(y^*/\alpha).$$

Combining (27) and (28) shows that the equilibrium depreciation rate is

$$(29) \qquad e_t - e_{t-1} = \lambda u_t + \frac{\lambda}{1-\lambda}(y^*/\alpha).$$

Notice that unless $\lambda = 0$, the economy is afflicted by a systematic inflation bias proportional to the deadweight output loss y^*. This bias results from the government's (in equilibrium, futile) attempts to exploit the potential short-run Phillips trade off due to the predetermination of nominal wages. A fixed exchange rate would eliminate this inflation bias, but it would also prevent the government from responding to unpredictable output shocks. Whether a fixed rate is advisable in light of this trade off is an empirical question.

In practice, governments cannot credibly commit to fix exchange rates between national currencies in all circumstances. A more realistic assumption, as in the last model, is that domestic policymakers face a fixed cost c of realignment, making period loss function in (26)

$$(30) \qquad \ell_t = \frac{\theta}{2}(e_t - e_{t-1})^2 + \frac{1}{2}[\alpha(e_t - w_t) - u_t - y^*]^2 + cZ_t,$$

where Z is defined as in (21).

How does the government behave under the loss function (30)? Remember that the government faces a pre-set nominal wage w_t when it decides its exchange rate for period t, and so, a predetermined expected rate of price inflation, $\pi_t = w_t - e_{t-1} = E_{t-1}(e_t) - e_{t-1}$. If the government maintains a fixed exchange rate (thus setting $e_t - e_{t-1} = 0$), (30) shows that its loss is

$$\ell_t^F = \frac{1}{2}(\alpha\pi_t + u_t + y^*)^2.$$

If the government realigns instead, it sets the exchange rate by (27) and incurs the fixed cost c, so its loss is

$$\ell_t^R = \frac{1}{2}(1-\lambda)(\alpha\pi_t + u_t + y^*)^2 + c.$$

Clearly a realignment will occur whenever

$$\ell_t^F - \ell_t^R = \frac{1}{2}\lambda(\alpha\pi_t + u_t + y^*)^2 - c > 0,$$

that is, when

$$(31) \qquad \frac{1}{2}\lambda(\alpha\pi_t + u_t + y^*)^2 > c.$$

Treating (31) as an equality and solving for its two roots, one finds upper and lower values for the shock u, $\underline{u} < \overline{u}$, such that the government devalues whenever $u > \overline{u}$ and revalues whenever $u < \underline{u}$. In either case, the government will set the new exchange rate at the *ex post* optimal level given by (27)(2).

(1) If the government could precommit its exchange-rate reaction function, it would choose the function $e_t - e_{t-1} = \lambda u_t$, that is, it would forswear accommodating wage shocks as well as any attempts to offset predictable real distorsions through currency depreciation. See Obstfeld (1991).

(2) There is no point in setting it at a different level because any new rate is fully incorporated into date $t + 1$ money wages.

In principle, an "escape-clause" arrangement of this sort (such as the one present in Stage Two of the plan for European Monetary Union) can raise welfare. It allows exchange-rate flexibility in those extreme situations where it is most needed, while restraining inflationary proclivities otherwise; and this effect provides a potential rationale for imposing a realignment cost c. In practice, however, a beneficial escape clause may be hard to implement. The reason for this difficulty, as (31) shows, is that the trigger points $\underline{u}$ and $\overline{u}$ at which the escape option is exercised depend on prior expectations of depreciation π_t, and these, in turn, depend on market perceptions of where the realignment trigger points lie. This element of circularity creates the potential for multiple equilibria, and a sudden shift in equilibria can trigger a crisis for an exchange rate that previously appeared strong on the basis of fundamentals.

To illustrate this possibility, it simplifies matters to assume temporarily that devaluation requires policymakers to pay a cost c, but that revaluations aren't possible at all. (The validity of this presumption will be verified later for a particular example.) For concreteness, the disturbance u_t is assumed to be uniformly distributed over the interval $[-\mu, \mu]$. I suppose that market participants believe the domestic currency will be devalued whenever a shock more severe than a threshold level $\overline{u}$ occurs (i.e., when $u_t > \overline{u}$). In an equilibrium, the market assessment of $\overline{u}$ equals the highest value of the shock at which the government still finds it optimal to defend the exchange parity.

Identification of equilibria requires two steps: (1) the calculation of market depreciation expectations given an anticipated devaluation threshold $\overline{u}$, and (2) calculation of the actual threshold given market expectations.

When market participants believe on date $t-1$ that the date t exchange rate will be changed if $u_t > \overline{u}$, they expect the date t depreciation rate to be

$$(32) \qquad \pi = Prob\,\{u_t \leq \overline{u}\}\cdot 0 + Prob\,\{u_t > \overline{u}\}\cdot E\{e_t - e_{t-1} \,|\, u_t > \overline{u}\},$$

where the last expectation is a date $t-1$ expected value of what depreciation will be next period conditional on u_t exceeding $\overline{u}$. (π is not a function of time because the shock u_t is serially independent.) Under the assumed uniform probability distribution for u_t,

$$Prob\,\{u_t > \overline{u}\} = \frac{\mu - \overline{u}}{2\mu}, \quad E\{u_t \,|\, u_t > \overline{u}\} = \frac{\mu + \overline{u}}{2}.$$

and, given the devaluation reaction function (27),

$$(33) \qquad E\{e_t - e_{t-1} \,|\, u_t > \overline{u}\} = \lambda\left(\frac{\mu + \overline{u}}{2\alpha}\right) + \lambda\pi + \lambda\,(y^*/\alpha).$$

Thus, (33) implies that

$$\pi = \left(\frac{\mu - \overline{u}}{2\mu}\right)\left[\lambda\left(\frac{\mu + \overline{u}}{2\alpha}\right) + \lambda\pi + \lambda\,(y^*/\alpha)\right],$$

which reduces to

$$(34) \qquad \pi = \delta(\overline{u}) = \lambda\left(\frac{\mu - \overline{u}}{2\mu}\right)\left[\left(\frac{\mu + \overline{u}}{2\alpha}\right) + (y^*/\alpha)\right] \div \left[1 - \lambda\left(\frac{\mu - \overline{u}}{2\mu}\right)\right].$$

The government takes the expectations in (34) as given and minimizes its loss. Equation (31) implies that the largest shock consistent with a continuing fixed exchange rate is a solution $\tilde{u}$ to the equation $\frac{1}{2}\lambda\,[\alpha\delta(\overline{u}) + \tilde{u} + y^*]^2 = c$. Since $\overline{u}$ must equal $\tilde{u}$ in equilibrium, and since, moreover, we are only interested in devaluation situations such that $\alpha\delta(u) + u + y^* > 0$[1], the condition for $\overline{u}$ to be an equilibrium devaluation threshold is that

$$(35) \qquad \sqrt{\lambda}[\alpha\delta(\overline{u}) + \overline{u} + y^*] = \sqrt{2c}.$$

(1) When this quantity is negative devaluation is never optimal but revaluation (which has been excluded) is.

Figure 8

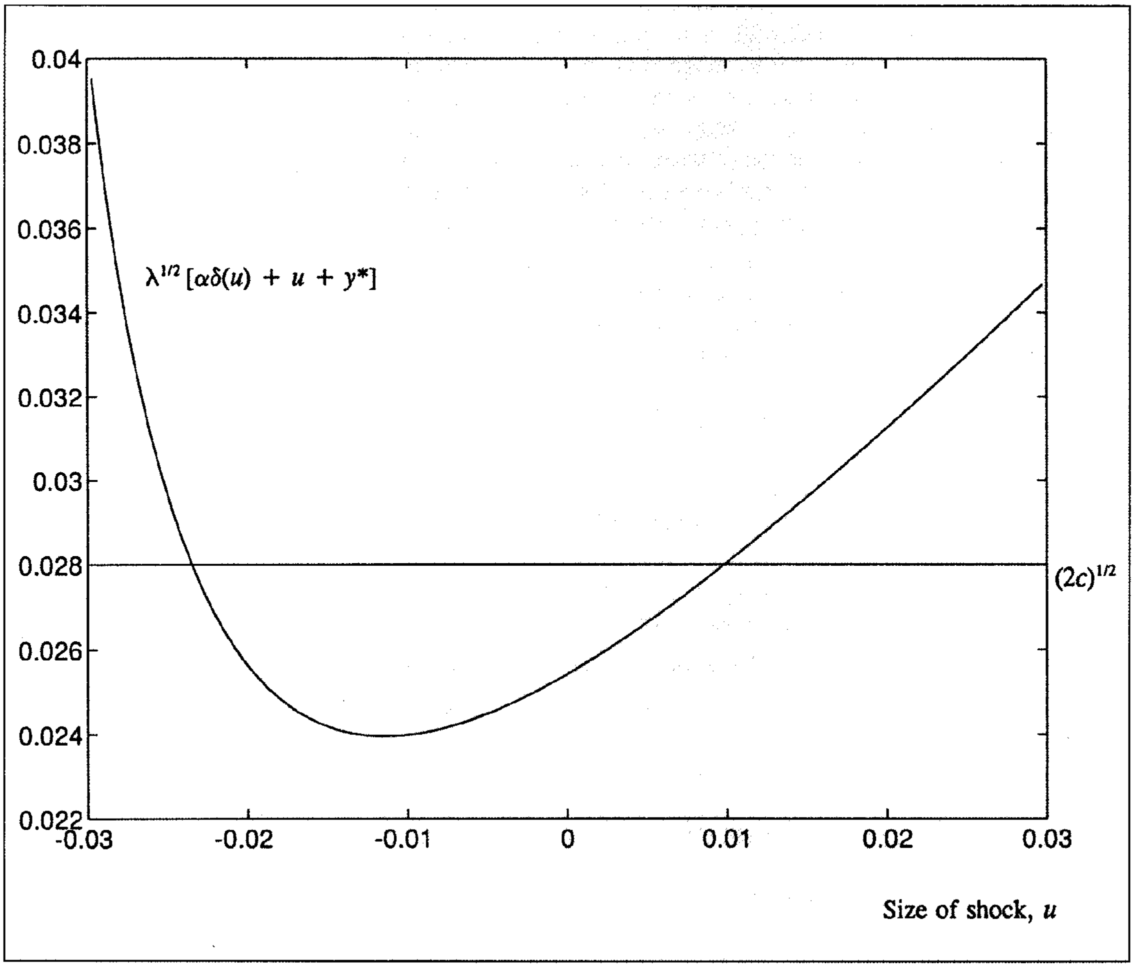


Figure 8 illustrates the possibility that there are multiple equilibrium thresholds. In the figure, there are two intersections of the function $\alpha\delta(u) + u + y^*$ with the (transformed) devaluation cost $\sqrt{2c}$. (The parameters underlying the figure are $\alpha = 1$, $\theta = 0.15$, $y^* = 0.01$, and $\mu = 0.03$ (1).) One threshold occurs at $\bar{u} = 0.0099$, and at it, the associated expected depreciation rate is $\delta(0.0099) = 1.23$ percent per period. The second equilibrium threshold is at $\bar{u} = -0.0234$. There, expected depreciation is $\delta(-0.0234) = 5.71$ percent per period. At this high expected depreciation rate, wage inflation creates a competitiveness problem and unemployment so painful that a devaluation will occur unless the output shocks hitting the economy are quite favorable. Thus, the relatively low credibility of the authorities in the second equilibrium is self-validating (2).

Economists so far have little to say about which particular equilibrium will occur in a situation where several are possible. In this model, however, any random event could trigger a shift from an equilibrium in which markets view devaluation as unlikely to one in which they view it as very likely. Figure 8 shows that the shift could even be from a situation where devaluation is viewed as impossible to one in which it is viewed as a near certainty. Such a shift would be accompanied by a sharp rise in

(1) The choices $\alpha = 1$ and $\theta = 0.15$ make $\lambda = 0.87$, which corresponds to a rather accommodative government. With distributions for u more complicated than the uniform, however, multiple equilibria (sometimes more than two of them) can arise under much less accommodative governments. See Obstfeld (1991).

(2) For the chosen parameters, note that when the public expects discretion to be exercised at $u = -0.03$ and above, the monetary authority has a substantial incentive to devalue, not revalue, even when $u = -0.03$. (Apply (34) and (35).) Thus, there was no loss of generality in assuming from the outset that revaluations never occur.

domestic interest rates and a loss in foreign reserves, and unless subsequent economic conditions turned out exceptionally favorably, a devaluation would likely ensue.

This scenario captures aspects of the EMS crisis that erupted in September 1992. Notice that reserve losses certainly accompany a crisis, but they are not the factor that triggers it and not the factor that ultimately leads the authorities to devalue. Even a version of the model without multiple equilibria suggests that negative output shocks can trigger devaluations. If such shocks are persistent (contrary to the assumption made above), higher interest rates and reserve losses will tend to precede realignment (1). Persistent output shocks can also throw the economy from a configuration with a sole equilibrium into one with several.

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If speculative currency crises are a manifestation of possible multiple equilibria, an obvious barrier to understanding them is the lack of any convincing account of how and when market expectations coordinate on a particular self-fulfilling set of expectations.

More generally, we have no more than an inkling of the factors that cause speculative attacks to occur on some days rather than on others. Obvious economic and political tensions can endure for some time before an attack occurs, with the proximate cause of the attack some seemingly trivial event that takes on significance only when viewed as the culmination of a series of signals concerning the economies involved and the resolve of their authorities. Thus, one can make cogent arguments as to why uncertainty over the Maastricht Treaty's future led to currency turbulence in the second half of 1992, but why was Black Wednesday not Black Tuesday or Black Thursday? To explain this timing (if indeed there is an explanation), one must postulate a model in which the market's response to a series of informative signals ultimately precipitates a crash. Caplin and Leahy (1994) explore such a model in the context of industry investment, but its heavy reliance on private information makes a direct extension to the foreign exchange market context problematic. More work on this problem is needed and under way.

The models developed in section 2 raise the basic question whether the crises they portray result from "fundamentals" or from "purely" self-fulfilling expectations. This dichotomy is a false one. The fundamental factors in these models are the dynamic-consistency problems implied by the preferences and constraints of governments. The constraints themselves are endogenous through their dependence on market expectations, and this critical endogeneity, combined with the authorities' inability to adhere to preordained rules, leads to multiplicity. Institutions that tie authorities' hands can eliminate the multiplicity problem. Absent such institutions, however, and given official objectives, the danger always exists that expectations produce equilibria in which the authorities prefer to abandon their prior exchange rate targets.

(1) Drazen and Masson (1993) present some empirical evidence supporting this mechanism as a component in determining the credibility of EMS exchange-rate commitments.

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