Perspectives on the

Recent Currency Crisis Literature

by

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ABSTRACT

In the 1990's, currency crises in Europe, Mexico and Southeast Asia have drawn worldwide attention to speculative attacks on government-controlled exchange rates. To improve our understanding of these events, researchers have undertaken new theoretical and empirical work. In this paper, we provide some perspective on this work and relate it to earlier research in the area. Then we derive the optimal commitment to a fixed exchange rate and propose a common framework for analyzing currency crises that draws from both the *first-generation* work and the more recent *second-generation* approach. The cross-generational framework stresses the important role of speculators and also recognizes that the government's commitment to a fixed exchange rate is constrained by other policy goals. In the final section we study the crisis prediction literature and find that some crises may be particularly difficult to predict using currently popular methods.

JEL classifications: F3, F4

Key words: currency crisis, speculative attacks

It is patently obvious that periodic balance-of payments crises will remain an integral feature of the international economic system as long as fixed exchange rates and rigid wage and price levels prevent the international price system from fulfilling a natural role in the adjustment process.

Robert A. Mundell
"A Theory of Optimum Currency Areas" (1961)

Introduction

In the 1990s, currency crises in Europe, Mexico and Southeast Asia have drawn worldwide attention to speculative attacks on government-controlled exchange rates. To improve understanding of these events, research has proceeded on both theoretical and empirical fronts. The purpose of this paper is to provide some perspective on this research and to relate it to earlier work in the area. The early work, now called *first-generation* research, responded to currency crises in developing countries such as Mexico (1973-1982) and Argentina (1978-81). These crises were preceded by overly expansive domestic policies. First-generation models show how a fixed exchange-rate policy combined with excessively expansionary pre-crisis fundamentals push the economy into crisis, with the private sector trying to profit from dismantling the inconsistent policies.

Newer models, the *second generation*, are designed to capture features of the speculative attacks in Europe and in Mexico in the 1990s. These attacks differ from the ones studied by the first-generation in two important ways: (1) in the countries experiencing the attacks, the state of the business cycle and the banking system as well as borrowing constraints imposed by monetary policies in partner countries handcuffed authorities and prevented them from using traditional methods to support exchange-rate parities; (2) the recent speculative attacks, particularly some of those in Europe, seemed unrelated to the economic fundamentals predicted by the first-generation models.

In this paper we begin in Section 1 by presenting the first-generation attack model developed by Salant and Henderson (1978), Krugman (1979) and Flood and Garber (1984b).[1] This model has been extended widely and a survey is provided by Agenor, Bhandari and Flood (1992). We also discuss some recent extensions of the model designed to capture features of the crises in the 1990s. In Section 2 we present examples of second-generation models. In this section we also extend these models by deriving the optimal commitment to a fixed exchange rate. The section concludes with a proposal for a common cross-generational framework. In Section 3 we examine empirical work that seeks to identify determinants of currency crises. Section 4 concludes.

[1] The first-generation model was developed by economists working at the Board of Governors of the Federal Reserve System. Building on Hotelling (1931), Federal Reserve economists Steven Salant and Dale Henderson (1978) built a speculative attack model to study attacks on a government-controlled price of gold. Soon after the Salant-Henderson model was drafted, Paul Krugman visited the Federal Reserve and recognized that the Salant-Henderson analysis could be applied to fixed exchange rates. This led to Krugman (1979). While Robert Flood was an Economist at the Federal Reserve, he and Peter Garber constructed a linear model that simplified Krugman's account and extended the model to a stochastic environment. The result was Flood and Garber (1984b). While Peter Garber visited the Federal Reserve, he and Herminio Blanco developed the first structural test of the first-generation model, Blanco and Garber (1986).

Section 1 - First-Generation Models

The canonical first-generation model is one of a small country that fixes the price of its currency in terms of the currency of a large foreign partner. Fixing the exchange rate is the responsibility of the domestic monetary authority, so the analysis revolves around private and government actions in the domestic money market.

Domestic money market equilibrium is given by

$$m - p = -\alpha(i) \; , \; \alpha > 0 \qquad (1)$$

where, in logs, m is the domestic supply of high-powered money, p is the domestic price level, and i is the domestic-currency interest rate in levels. The domestic money supply is backed by two central bank assets, domestic credit, whose log is d, and international reserves, whose log is r. As an accounting identity, in levels, the high-powered money supply is equal to the sum of domestic credit and international reserves. We log-linearize this identity as:[2]

$$m = d + r \; . \qquad (2)$$

The domestic-currency interest rate and price level are subject to international arbitrage conditions. The price level is governed by purchasing power parity:

$$p = p^{*} + s, \qquad (3)$$

where p* is the log foreign price level, usually held constant by assumption, and s is the log exchange rate quoted as the domestic-currency price of foreign exchange. The interest rate obeys uncovered interest rate parity:

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[2] For expositional purposes we adopt a simple linearization in equation (2). In empirical work, however, money might be log linearized as $m_t = a_o + a_1 d_t + a_2 r_t$, where $a_1 = D_t/M_t$ and $a_2 = (1 - a_1)$ at the point of linearization, usually the sample mean.

$$i = i^* + \dot{s}. \tag{4}$$

where i* is the foreign-currency interest rate and $\dot{s}$ is the expected and actual rate of exchange rate change.

The standard exchange-rate model outlined above is chosen for its simplicity rather than for its empirical performance. The basic ideas apply equally well to more complicated models. In the foregoing model, during a fixed exchange-rate period, the domestic price level moves in lockstep with the foreign price level. The domestic-currency interest rate is equal to the foreign-currency interest rate and the quantity of international reserves adjusts to balance the money market. During a flexible exchange-rate regime, the quantity of international reserves is normally held fixed and the exchange rate is free to balance the money market. In applications of the model, or when using the model to discuss historical episodes, the money market is expanded to include such features as a money multiplier, a role for home-good prices, a scale variable such as income, consumption or wealth and a money-market disturbance.[3]

In a world of certainty and with the exchange rate fixed at $s=\bar{s}$, it follows that $\dot{s} = 0$ and $i = i^*$. Suppose that deficit financing requires domestic credit to grow at a constant rate, μ, and that i* and p^* are constant. Substituting from equations (2), (3) and (4) into equation (1) with $\dot{s} = 0$, it follows that:

$$r + d - p^* - \bar{s} = -\alpha(i^*) \tag{5}$$

When the exchange rate, foreign price and foreign interest rate are fixed, d grows at the rate μ and r falls at the same rate, $\dot{r} = -\mu$. Clearly this country will run out of reserves eventually

[3] With the money market expanded appropriately, the model was applied to Mexican data in Blanco and Garber (1986) and to Argentine data in Cumby and van Wijnbergen (1989).

and the fixed rate will break down. To analyze the breakdown, we need to describe precisely what the government does when it runs out of reserves. Different plans for government behavior in the crisis turn out to influence the timing and size of the crisis.

In a crisis, most governments either allow the exchange rate to float, as did Mexico in 1994, or devalue the domestic currency from one fixed rate to another, as happened in most European countries in 1992-1993. Suppose that in a crisis speculators purchase the remaining government stock of foreign-exchange reserves dedicated to defending the fixed rate and then the government allows the exchange rate to float. We know that the fixed rate must break down eventually, but when? To find the time of the attack, we introduce the idea of the *shadow exchange rate*, which is defined to be the floating exchange rate that would prevail if speculators purchase the remaining government reserves committed to the fixed rate and the government refrains from foreign exchange market intervention thereafter. The shadow rate is crucial to assessing the profits available to speculators in a crisis as this is the price at which speculators can sell the international reserves that they buy from the government.

The shadow exchange rate, $\tilde{s}$, therefore is the exchange rate that balances the money market following an attack in which foreign exchange reserves are exhausted.[4] The exchange rate that solves the post-attack money market is consistent with:[5]

[4] In general, the shadow rate is influenced by the amount of reserves the government continues to hold following its optimal defense of the fixed rate. For now, we set the log of reserves at zero after the attack. See section 2.2 for further discussion of this point.

[5] For simplicity we set $i^* = p^* = 0$.

$$d - \tilde{s} = -\alpha(\tilde{s}) \qquad (6)$$

That exchange rate is:

$$\tilde{s} = \alpha\mu + d \ . \qquad (7)$$

In Figure 1 we plot equation (7) and the pre-attack fixed exchange rate. The two lines intersect at point A, where $d = d^A$.

Suppose that d is smaller than d^A. If speculators attack at such a level of d then post-attack the currency will appreciate and speculators will experience a capital loss on the reserves they purchase from the government. There will be no attack, therefore, when $d < d^A$. Suppose instead that speculators wait until $d > d^A$. Now $\tilde{s} > \bar{s}$, meaning that there is a capital gain to speculators for every unit of reserves purchased from the government. Speculators can foresee that capital gain and will compete against each other for the profit. The way they compete is to get a jump on each other and attack earlier. Such competition continues until the attack is driven back in time to the point where $d = d^A$. It follows that a foreseen attack must take place when $\bar{s} = \tilde{s}$. Exchange-rate jumps are ruled out by speculative competition.

Let the size of the speculative attack be Δr, which is negative in an attack. From equation (7), the exchange rate will begin rising at the rate μ after the attack. Therefore, interest parity requires that the domestic-currency interest rate jump up by μ. This point is key to the first-generation models -- at the time of a foreseen speculative attack, the domestic-currency interest rate must jump upward to reflect prospective currency depreciation.

Two things therefore adjust in the money market at the time of the attack: (1) the high-powered money supply drops by the size of the attack and (2) the demand for domestic currency drops because the domestic-currency interest rate increases to reflect prospective currency depreciation. Money-market balance at the instant of the attack requires the drop in money supply to match exactly the drop in money demand, so $\Delta r = -\alpha\mu$. Since domestic credit follows $d_t = d_0 + \mu t$, international reserves follow $r_t = r_0 - \mu t$. At the time of attack, T, reserves fall to zero. The condition for the attack becomes $-\Delta r = r_0 - \mu T = \alpha\mu$. Rearranging terms, the attack time is[6]

$$T = \frac{r_0 - \alpha\mu}{\mu} \qquad (8)$$

Equation (8) shows that the higher the initial stock of reserves or the lower the rate of credit expansion, the longer it takes before the fixed exchange rate regime collapses.

Section 1.1 - Modified First-Generation Models

The first-generation model equates the attack-caused drop in the domestic money supply with the drop in money demand induced by higher domestic-currency interest rates. The interest rate must rise to reflect post-attack currency depreciation. In the 1990s crises, the money-supply effects of reserve losses were sterilized, allowing smooth money growth through the attack period.

What happens when sterilization policies are incorporated into the standard model? Let us return to the model above but now hold the money supply constant through the attack, so $m = \bar{m}$. While the exchange rate is fixed, money-market equilibrium is:

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[6] Similar timing equations are derived in Connolly and Taylor (1984) and Flood and Garber (1984b)

$$\bar{m} - p^{*} - \bar{s} = -\alpha(i^{*}) \qquad (9)$$

Following an attack, international reserves are exhausted, the economy switches to a flexible exchange rate and the money supply begins to grow at the rate $\mu > 0$. In that situation, the flexible exchange rate $\tilde{s}$ will rise also at the rate μ. Interest parity ensures that the domestic interest rate will be $i = i^{*} + \mu$. Just after an attack, therefore, domestic money market equilibrium will be:

$$m - p^{*} - \tilde{s} = -\alpha(i^{*} + \mu) \qquad (10)$$

Subtracting equation (10) from equation (9) reveals:

$$\tilde{s} - \bar{s} = \alpha\mu > 0 \qquad (11)$$

Equation (11) shows that $\tilde{s}$ is greater than $\bar{s}$ *no matter how high the authorities set* $\bar{s}$ *or how great the quantity of international reserves held by the monetary authority*. In other words, the simple model predicts that no fixed exchange-rate regime can survive, even for a moment, if the monetary authority plans to sterilize an attack and those plans are understood by speculators.[7]

Complete sterilization evidently presents a problem for the simple model since it implies that fixed exchange rates are incompatible with complete sterilization. Yet fixing the exchange rate while sterilizing is common practice. This type of model can be (somewhat) rehabilitated, however, by recognizing that what sterilization does is remove the attack from the money-market and push it off into another market. Sterilizing an attack on the country's foreign-exchange

[7]The importance of this point is hard to overemphasize. If the monetary authority is unwilling to allow monetary policy to play a secondary role to exchange-rate policy - at least some of the time - then *any* fixed rate backed by *any* quantity of international reserves is at risk when capital is freely mobile. This conclusion contrasts strongly with much advice concerning "sufficient" reserve backing of currency pegs.

reserves usually involves the monetary authority's expanding domestic credit and using it to purchase domestic government securities. The change in outstanding asset quantities is therefore shifted from the money market to the market for domestic bonds.

Flood, Garber and Kramer (1996) pursue the speculative attack from the money market, where it resides in the standard model, into the bond markets, where it is driven by domestic sterilization operations. Monetary policy is the same as before except the attack itself is sterilized. Thus domestic credit still grows at the rate μ and is invariant to the speculative attack. Instead of the uncovered interest parity condition in equation (4), however, we now add a bond-based risk premium to the spread between domestic and foreign-currency interest rates. The domestic-currency interest rate is now:[8]

$$i = i^{*} + \dot{s} + \beta(b - b^{*} - s) \qquad (12)$$

where $\beta > 0$ is a constant, in logs b is the quantity of domestic government bonds in private hands and b^* is the quantity of foreign-currency bonds in private hands.

Printing domestic credit at the rate μ creates incentives for private portfolio reallocation and ends up pushing international reserves out of government hands and into the private sector. Those reserves are interest-paying foreign-currency securities and as reserves decline, b^* rises. After accounting for private accumulation of reserves, the rate of change of reserves is now $\dot{r} = -\mu / (1 + \alpha \beta)$. Previously the attack was timed to avoid an exchange rate jump. The money supply jump exactly matched the money demand jump so the exchange rate did not change at the moment of the attack. Now, since the money supply is unresponsive to the speculative

[8] See Willman (1988).

attack and since we still prohibit the exchange rate from jumping, the maintenance of money-market equilibrium requires the additional condition that the domestic-currency interest rate not jump at the time of a foreseen attack. It is evident from inspecting equation (12) that the speculative attack will therefore be timed so the upward jump in $\dot{s}$ exactly matches the downward jump in the risk premium.[9]

By adding a risk premium to the simple interest parity condition, we now have a model where sterilization is compatible with a fixed exchange rate. The risk premium adjusts to keep constant the demand for money while sterilization holds the money supply fixed. Yet the introduction of a risk premium into a perfect foresight model is an anomaly, to say the least.[10]

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[9]After an attack the exchange rate reverts to its shadow value, $\tilde{s}$. For this portfolio-balance model of the exchange rate, the shadow rate is given by: $\tilde{s} = \kappa_0 + \kappa_1 d$, where $\kappa_1 = 1/(1 + \alpha\beta)$. At the instant of the attack $\dot{s}$ jumps from zero to $\kappa_1 \mu$ and the risk premium jumps down by $\beta 2 \Delta r$, where Δr is the size of the attack. The 2 enters this expression because the attack is sterilized. The government uses domestic high-power money to buy domestic securities and compensate for the reserve loss, thereby decreasing the risk premium. In addition, the reserves held by the domestic central bank are now in private hands, reducing the risk premium again by the size of the attack.

When does this attack occur? The attack takes place when the interest rate will not jump and that happens when $\kappa_1\mu = -\beta 2 \Delta r$. Therefore, the attack size is $\Delta r = -\kappa_1 \mu/(2\beta)$. During the fixed-rate period reserves follow $r(t) = r(0) - (\mu t/(1+\alpha\beta))$. Since the attack takes place precisely when r $= \Delta r$, it follows that the attack takes place when:

$$T = \frac{r(0)(1 + \alpha\beta)}{\mu} - \frac{1}{2\beta}$$

As $b \to 0$ the attack is pushed toward the present.

[10] It is tempting to dismiss sterilized intervention because of poor empirical performance (see e.g. Frankel (1984)), but that may be an overreaction. Recall that *no* exchange-rate or other asset-price model or any simple (nonarbitrage) parity condition works well for high-frequency post-WWII industrial-country data. Our asset market models serve, however, as intellectual organizing devices for discussions about foreign-exchange and other asset markets.

Section 1.2 - Attacks in Uncertainty

Thus far we have presented models of perfectly foreseen speculative attacks. This is not because attacks are foreseen perfectly, but to show in a simple setting the underlying economic structure of how the private sector responds to inconsistent economic policies. The important contribution of the first-generation models was to show that a large asset-market event - an attack - need not be associated with a large shock. Indeed, in our examples so far there are no shocks. When using these models to interpret recent events, however, uncertainty becomes a crucial element. Market participants are never sure when an attack will take place and they are never sure by how much the exchange rate will change if there is an attack. This uncertainty is reflected in data in that domestic-currency interest rates often rise in anticipation of a crisis.

In the certainty models, the process of fixing an exchange rate that is eventually attacked involves no transfer of wealth from the government to currency speculators. Yet in real-life crises, some people get rich, often at the expense of the government's price fixing authority. The wealth transfer occurs when agents can buy international reserves from the government at the fixed exchange rate and resell those same reserves immediately at a higher post-crisis exchange rate. With uncertainty, the fixed rate system - with the possibility of attack - provides a free *call option* given by the exchange-rate authority to speculators. Extending this analogy, the fixed exchange rate is the option's *strike price* and the quantity optioned is the amount of international reserves backing the fixed exchange rate. Of course, one important difference between an actual market-traded option and the option on the fixed exchange-rate policy is that a clear set of property rights comes with the market-traded option but not with the policy option. In an attack, it is not clear how large the reserve commitment is nor how the commitment will be allocated. Will reserves be allocated on a first-come-first-served basis? Will they simply be given to favored insiders? Such pre-attack allocation uncertainty helps explain the crisis atmosphere surrounding actual attack episodes.

For current purposes, however, the important point is that the methods used in options pricing are relevant to understanding the behavior of speculators during a crisis period. In particular, when pricing an option on an asset, the mean and variance of that asset's price as well as other properties of the price distribution are relevant. For this reason, most of the speculative-attack/crisis literature in an uncertain environment relies on specific examples of the distribution function for underlying disturbances. As we shall see below, distribution shapes as well as the usual central moments (mean and variance) can affect policy conclusions.

In one paper where distribution shape matters, Flood and Marion (1996) construct a model with full sterilization and a risk premium in an explicitly stochastic environment. In their set up, the risk premium is derived from expected utility maximization and the monetary base is held constant before, during and after the crisis period. With these modifications, the interest parity relation becomes:

$$i = i^* + E_t \tilde{s}_{t+1} - \tilde{s}_t + \beta_t (b_t - b^*_t - \tilde{s}_t) \qquad (13)$$

which differs from equation (12) in two respects. First, equation (13) embeds the risk premium in a discrete-time stochastic framework rather than in a continuous time, perfect foresight one. Second, the coefficient β is now subscripted by t, meaning it can change period by period. In particular, if agents maximize expected utility that is increasing in expected wealth and decreasing in the variance of wealth, then $\beta_t = zVar_t(\tilde{s}_{t+1})$, where z is a taste-determined constant and is the conditional variance of the period-ahead shadow rate.

The model contains a nonlinearity in private behavior that admits multiple solutions. From equation (13) we see that if agents come to expect more currency variability in the future (a bigger $Var_t(\tilde{s}_{t+1})$), it affects the domestic interest rate through the uncovered interest parity relation and feeds into the demand for money, making the exchange rate more variable should the fixed rate be abandoned. The shift in expectations, therefore, alters the relevant shadow rate for determining whether an attack is profitable and changes the attack time. With a time-varying stochastic risk premium, currency crises can still be the outcome of inconsistent policies, an important message of the standard first-generation model, but crises can now arise also from self-fulfilling prophecies about exchange-market risk for some range of fundamentals. Nonlinearities in private behavior can thus be an additional source of currency crises. Their existence suggests that an economy can jump suddenly from a no-attack equilibrium to an attack equilibrium.

Section 2. Regime-Conditional Policy: An Introduction to Second-Generation Models

The standard first-generation model combines a linear behavior rule by the private sector --the money demand function-- with linear government behavior-- domestic credit growth. All of this linearity interacts with the condition that perfectly foreseen profit opportunities be absent in equilibrium to produce a unique time for a foreseen future speculative attack. Second-generation models abandon the requirement of linear behavior, which often then leads to multiple solutions. That nonlinear behavior rules by one or more agents can lead to multiple solutions in a model is no surprise to students of economics. An attribute of second-generation models is that they take seriously one or more nonlinearities ignored previously.

Second-generation models focus on potentially important nonlinearities in government behavior. They study what happens when government policy reacts to changes in private behavior or when the government faces an explicit trade-off between the fixed exchange-rate policy and other objectives. Some of the newer models show that even when policies are consistent with the fixed exchange rate, attack-conditional policy changes can *pull* the economy into an attack. In contrast, first-generation models generate an attack by having inconsistent policies before the attack *push* the economy into a crisis. Other models show that a shift in market expectations can alter the government's trade-offs and bring about self-fulfilling crises. The newer models admit the possibility that the economy can be at a no-attack equilibrium where speculators see but do not pursue available profit opportunities. In such a situation, anything that serves to coordinate the expectations and actions of speculators can suddenly cause an attack.

Second-generation models emphasize multiple equilibria arising from nonlinearities in government behavior. These nonlinearities have been introduced in a variety ways in the literature. Our strategy in presenting this work is to illustrate in some detail two examples of these nonlinearities.

Example 1

We begin by introducing a policy nonlinearity into the standard first-generation model we have described already.[11] The policy nonlinearity we consider is a conditional shift in the growth

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[11] This nonlinearity was suggested to Flood and Garber in private correspondence by Steven Salant. It first appeared in print in Flood and Garber (1984a), which was initiated in a set of briefing memos to the Federal Reserve governors serving on the Gold Commission. This nonlinearity was developed further by Obstfeld (1986b). Another early example is presented in Calvo (1988).

rate of domestic credit. If there is no attack on the fixed exchange rate, domestic credit grows at the rate μ_0; if there is an attack, domestic credit grows at the faster rate μ_1.

Figure 2 duplicates Figure 1, but now there are two shadow exchange-rate lines, one corresponding to a rate of credit expansion μ_0 and a higher one related to the higher rate of credit expansion μ_1. The shadow-rate line for μ_0 intersects the $\bar{s}$ line at point A and the shadow rate line for μ_1 intersects at point B. For illustration purposes, suppose that $\mu_0 = 0$ so that for this policy setting the fixed rate would survive indefinitely for some amounts of domestic credit.

Suppose now that d lies in the range to the left of d^B. If there is no attack, the shadow rate is on the $s_{\mu o}$ line. If speculators attack, the shadow rate jumps to the $s_{\mu 1}$ line, which is still below the fixed exchange rate. Since any attack leads to capital losses for speculators, there is no incentive to attack the fixed exchange rate if domestic credit is less than d^B. When domestic credit is not growing ($\mu_0 = 0$), the fixed exchange-rate policy is compatible with domestic credit policy and the fixed rate survives indefinitely.

Now suppose that domestic credit is at the level d^B, where the $s_{\mu 1}$ shadow-rate line intersects the $\bar{s}$ line. With $\mu = \mu_0$, the shadow rate is on the lower line at point C. If speculators attack the fixed rate, the shadow rate jumps from C to B. The attack is successful, but there is no profit for speculators since there is no immediate capital gain on the reserves purchased from the monetary authority. The economy can sit indefinitely at point C or it can move to point B in a speculative attack that ends the fixed exchange-rate regime. Equilibrium can occur at either point B or C, but no unrealized profit opportunities drive the economy from point C to point B.

If domestic credit is in the range between d^A and d^B, then multiple equilibria may be possible if speculators are small and uncoordinated as a group or face costs in confronting the government. The economy could reside on the lower shadow rate line indefinitely if agents believe there is no chance that the market will mount an attack. At the other extreme, the economy could jump to the higher shadow rate line if agents are convinced there will be a run on the currency. Convinced of a run, no individual speculator will find it profitable to hold domestic currency since this would result in a sure capital loss when the run occurs. Consequently, all agents will participate in an attack, leading to a collapse of the fixed rate and more expansionary credit policy.

Do multiple equilibria exist when fundamentals range between d^A and d^B ? If a large trader can take a massive position against the fixed exchange rate, as George Soros supposedly did against sterling in 1992, then there may be no multiple equilibria. The economy faces only the attack equilibrium since the well-financed speculator always moves to exploit available profit opportunities. But suppose there is no large trader in the foreign exchange market, only many small credit-constrained ones. Then without anything to coordinate their expectations and actions, they cannot mount an attack of sufficient size to move the economy from the no-attack equilibrium to the attack equilibrium. Then, as suggested in Obstfeld (1986b), there are multiple equilibria. The economy can maintain the fixed exchange rate indefinitely unless something coordinates expectations and actions to cause an attack.

The multiple equilibria story provides no explanation of the coordination mechanism---of what causes attacks to occur when they do. When individuals have common knowledge concerning the fundamentals---domestic credit policy in our example---then an explanation of the onset of an attack must appeal to an *ad hoc* shift in everyone's expectations to move the economy from the no-attack to the attack equilibrium. Ideally, we would like a rationale for the shift in expectations or an understanding of the mechanism for coordinating such a shift.

Morris and Shin (1995) show how some types of uncertainty can eliminate multiple equilibria and make the attack outcome the unique one. They describe a speculative game in which each economic agent obtains information about the state of the economy (domestic credit in our example), but with a small amount of error. Specifically, if the true state of the economy is $\bar{d}$, the agent observes a message that lies in the interval $[\bar{d}-\epsilon,\ \bar{d}+\epsilon]$, where ϵ is a small positive number and messages are independent across agents. With noisy differential information, it is never common knowledge that the fixed exchange rate is sustainable. Consequently, each investor must consider the full range of possible beliefs held by others and must contemplate what to do if the parity is unsustainable. If there is a good chance other speculators believe the fixed exchange rate is unsustainable, and if it is not too costly to take a position against the currency, then it makes sense for the individual investor to speculate, even knowing the peg is otherwise viable. Holding onto the currency may yield a bigger gain if everyone else holds on as well, but it is a riskier course of action because it relies on everyone else behaving similarly. Consequently, the only equilibrium in the region bounded between d^A and d^B is the attack equilibrium.[12]

The 1992-93 currency crisis in Europe has been cited as a case where extreme beliefs

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[12]Morris and Shin (1995) show that multiple equilibria can exist for some departures from perfect information. For instance, if all investors observe a public signal about the true state of fundamentals, then the signal is common knowledge and the state of fundamentals is commonly known even if the signal does not give an accurate picture of the fundamentals. In such a situation, it is possible to have multiple equilibria.

moved the market. While the Bundesbank's lukewarm support of some exchange-rate mechanism (ERM) parities was well known in 1992, each new announcement by central bank officials caused commentators to debate anew the strength of the German commitment. In such a situation, even if an investor believes the fixed exchange rate to be sustainable, he has to worry about whether others interpret official announcements the same way. Therefore, a crisis can be caused by traders worried about the beliefs of others.

A related but separate explanation for the onset of a currency attack is information cascades. The cascades story, described in more detail in Banerjee (1992) and Bikhchandani, Hirshleifer and Welch (1992), relies on actual observations of others' actions and, in contrast to Morris and Shin (1995), the lack of common knowledge about the state of fundamentals plays no important role. Although the information cascade phenomenon has not been formally applied to currency attacks, the argument might go as follows.[13] Suppose each investor has some information about the state of the economy (in our set up, about the range for domestic credit) and decides sequentially and publicly whether to hold the currency or sell it. If the first n investors happen to receive bad signals and sell, then the (n+1)th investor may choose to ignore his own information--even if it is positive about the viability of the fixed exchange rate--and sell, based on the revealed information of those who came before him. This sequential decision rule results in "herd" behavior. People will be doing what others are doing rather than using their own information. Consequently, if some traders start selling the currency, others will join the herd, moving the economy from the no-attack to the attack equilibrium.

While there may be some elements of a cascades story in currency attacks, there are

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[13]The argument is presented in Morris and Shin (1995).

reasons to think that it is not the whole story. First, in an environment where traders can adjust their strategies continuously to new information, it is unlikely that individuals ignore their own information or new information. (Lee (1993) and Morris and Shin (1995)). Second, if strategic interactions are important, it may be unsatisfactory to rely on a cascades story where the potential capital gain arising from the action of one agent does not depend on the actions chosen by others. (See Morris and Shin (1995)).

Calvo and Mendoza (1997) depart from the sequential decision-making framework in Banerjee and consider instead a global market with many identical investors forming decisions simultaneously. They show that with informational frictions, herding behavior may become more prevalent as the world capital market grows. Globalization reduces the incentives to collect country-specific information to discredit rumors and increases the likelihood that fund managers who worry about their relative performance will each select the same portfolio. Consequently, small rumors can induce herding behavior and move the economy from the no-attack to the attack equilibrium.

Where does all this leave us? In the model described by Figure 2, where policy responds to an attack, we can characterize four situations depending on the size of the state variable, d. In the first situation, $d < d^B$ and the post-attack policy shift offers no incentive to attack. In the second situation, $d = d^B$ and there is no profit in an attack but neither is there a loss. Points B and C are both viable equilibria. The economy can experience an attack or not depending on speculators' animal spirits rather than on profit opportunities. In the third situation, $d^B < d < d^A$ and multiple equilibria are possible if there are many small traders who must wait for some mechanism to coordinate their actions. The fourth situation occurs when $d \geq d^A$. Here, the fixed exchange rate is attacked.

Example 2

The second example of policy nonlinearity comes from Obstfeld (1994), who derived a closed-form solution for a monetary rule with an escape clause.[14] We present a simplified version of the Obstfeld model and use it as a vehicle to illustrate: (1) the role of an explicitly optimizing government, (2) the surprising policy implications present in many models that admit multiple solutions, (3) the optimal degree of commitment to a fixed exchange rate or, alternatively, the optimal attack frequency, and (4) a suggested reconciliation of first and second-generation approaches.

In the Obstfeld model, the government's optimizing behavior is at the center of the analysis and private behavior is kept in the background. Suppose that the government conducts exchange-rate policy according to:

$$\min\ L = \frac{\theta}{2}\delta^2 + \frac{(\delta - E\delta - u - k)^2}{2} \tag{14}$$

L is the social loss function; δ is the rate of currency depreciation; $E\delta$ is the expected rate of currency depreciation, u is a zero-mean disturbance with variance σ^2, k is a measure of distortion

[14] Rules with an escape clause were introduced by Flood and Isard (1989) and studied by Persson and Tabellini (1990) and Lohmann (1992).

and θ is the relative weight attached to price changes.[15] All of the variables in this model are realized in the same period except the expectations operator, E, which is based on past information, so we drop the time dating. Two modes of policymaking are studied normally: (1) a rule and (2) discretion. The rule requires the government to set policy regardless of the current state of the economy (e.g., the disturbance u) and discretion allows the government to set policy after observing the state, including predetermined expectations.

Equation (14) is an adaptation of the Kydland and Prescott (1977), Barro and Gordon (1983) model of *time inconsistent* policymaking. Kydland and Prescott showed that policymaking is systematically inflationary when it is based on predetermined expectations in a distorted environment. The government is tempted each period to exploit predetermined private expectations to expand the economy and overcome the distortion. The private sector understands the nature of the temptation that the government faces, however. The private sector therefore expects inflation (devaluation in Obstfeld's model) and it turns out to be optimal for the government to validate that expectation.

We calculate the expected value of the loss function in (14) first for the rule, which we take to be a fixed exchange rate $(\delta = 0)$, and then for discretion. Forming expectations in accord with the rule, the private sector sets $E\delta = 0$ so that:

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[15]Time-series variation in employment shocks may be embedded in k. Equation (14) is a simpler version of the loss function in Obstfeld (1994). It captures the government's attempt to minimize both actual price changes and a function of unexpected price changes. The government wants to minimize actual price changes for credibility reasons or to reduce distortions in cash balance holdings. The government wants to minimize a function of unexpected price changes to stabilize employment or business cycles.

$$EL^R = \frac{\sigma^2 + k^2}{2} \qquad (15)$$

where EL^R is the expected value of the loss function if the government follows the rule. If the government follows discretion, the private sector understands this policy and forms $E\delta^D = k/\theta$. Then (with $\theta = 1$ for simplicity) the expected value of the loss function becomes:

$$EL^D = \frac{\sigma^2}{4} + k^2 \qquad (16)$$

Equations (15) and (16) illustrate the Kydland and Prescott result: Absent shocks $(\sigma^2 = 0)$, society is unambiguously worse off with discretion than with a rule, but when the rule cannot stipulate the course of action for every possible shock that could hit the economy, discretion may be superior. Clearly EL^D is better than EL^R for sufficiently high σ^2 relative to k.

More generally, the government should pursue a mixed strategy - follow the rule most of the time but invoke an escape clause from time to time when the disturbance turns out to be particularly disruptive. Of course, it must be made costly to the government to invoke the escape clause, otherwise discretion will always be followed. With an escape clause, the government follows the rule whenever:

$$L^R < L^D + C \qquad (17)$$

where C is a cost imposed whenever the escape clause is chosen. In Obstfeld's example, invoking the escape clause means devaluing the currency.

For a given value of C, the policymaker's problem is to decide the value of the disturbance that triggers the escape clause. That value is $\bar{u}$, where $\bar{u}$ solves:

$$L^R(\bar{u}) = L^D(\bar{u}) + C \qquad (18)$$

Equation (18) is nonlinear in part because of the statistical problem individuals face at the beginning of the period when forming their expectations about the rate of currency depreciation. Before they see whether the rule or discretion is chosen, individuals set their expectation about the rate of currency depreciation by calculating a probability-weighted average of the expected rate to be chosen under the rule, $E\delta^R = 0$, and the expected rate to be chosen under discretion, $E\delta^D > 0$.

We portray in Figure 3 the nonlinear problem as presented in Obstfeld (1994). In the figure, the curved line plots (a function of) L^R-L^D and the horizontal line represents (a function of) an arbitrary level C.[16] The two lines intersect twice, once at a low value for the disturbance, $\bar{u}_L$, and again at higher one, $\bar{u}_H$. If the private sector adopts $\bar{u}_H$ as its belief about the level of the disturbance at which the government will abandon the rule, then the government finds that adopting this value solves the government's optimization problem as well. Consequently, this value of the disturbance is the one that triggers the escape clause. Similarly, if the private sector adopts $\bar{u}_L$ as its belief about the trip switch, then it is optimal for the government to adopt this value instead.[17]

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[16]The curved line is actually $\sqrt{2(L^R - L^D)}$ and the horizontal line is $\sqrt{2C}$. See Obstfeld (1994) for the specific functional forms for L^R and L^D.

[17]As in Obstfeld (1994), we focus only on the interior solutions. The horizontal line at $\sqrt{2C}$ intersects the vertical axis. This left intersection is also an equilibrium of the model. This equilibrium will become an interior one in the normal distribution example in the next section.

Flood and Marion (1997) study the policy implications of taking seriously both equilibria depicted in Figure 3. They find that in an environment where the economy can jump from one equilibrium to another, increasing the cost of abandoning the fixed exchange rate may make a crisis more likely. This is clear from Figure 3. If the economy regularly finds itself at equilibrium L_o, then raising C by a small amount lowers the value of the disturbance that triggers an attack and makes the crisis more likely.

C may be thought of as commitment staked on the fixed exchange rate. For example, convergence of the European Monetary System toward European Monetary Union is an increase in the cost of breaking the fixed exchange-rate arrangement. According to this model, when multiple equilibria are a serious empirical possibility, tightening the commitment to the fixed rate may be exactly the wrong policy prescription. Raising the cost might make crises more frequent.[18]

Section 2.1 Optimal Commitment to a Fixed Rate

Usually the cost of breaking the rule is interpreted as the loss to the government of reputation or credibility or the deadweight loss to society as a whole. Isard's (1995) work suggests another interpretation. The cost can be viewed, at least in part, as the capital gain foregone by the monetary authority---or the capital gain awarded to speculators--- in the event the domestic currency is devalued. What is relevant to speculators is the size of the prospective devaluation multiplied by the reserve loss tolerated by the authority during a crisis. If this amount is small, the defense is half-hearted. If it is very large, then the currency peg may be nearly

[18]If the private sector's expectations about future currency depreciation are dampened by increasing the opting-out cost, there may be less chance of the economy jumping to the lower equilibrium. But as long as there is the possibility of multiple equilibria, one equilibrium behaves perversely.

permanent.

Isard's (1995) interpretation is particularly nice in the present context for two reasons. First, it allows us to use economic incentives to distinguish among equilibria in Obstfeld's model. Suppose that a certain portion of the cost is distributed to speculators each time the fixed rate is attacked successfully. Other things equal, speculators prefer to settle on the solution where attacks are *most frequent.* This suggests that the economically relevant solution in these models is always at the lowest $\bar{u}$ solution. Second, interpreting this cost as (in part) the commitment to the fixed exchange rate leads naturally to thinking about the optimal commitment.

Viewed in this way, recent research on currency crises provides an interesting extension to Mundell's (1961) famous analysis of optimal currency areas. While Mundell's work directed attention toward forming permanent cross-country (or cross-area) currency arrangements, events have shown that all cross-country currency arrangements are ultimately temporary. Policymakers realize that they are faced with two important decisions. Not only do they have to select the appropriate exchange-rate arrangement, they must worry also about how tightly to hold onto it. For countries adopting a fixed exchange rate, does research on currency crises provide any guidance about how strongly to defend a parity?

One answer to this question lies just below the surface in many second-generation models.[19] Suppose the cost imposed on the government when it breaks the fixed exchange-rate rule is not a fixed parameter. While the cost must be exogenous from the monetary authority's

[19] See eg., Obstfeld (1997).

perspective, it may be chosen by some higher entity ("society") to minimize expected social loss.[20] This optimal cost can be interpreted as the optimal level of support for the fixed rate. What is the size of this optimal cost? What does it imply for the optimal attack frequency?

We explore these questions in a pair of simulation models that differ only in their assumptions about the shape of the shock distribution hitting the economy. We consider two well-known distributions --- uniform and normal --- and find that the optimal level of support for the fixed exchange rate depends on the distribution of the shock.[21]

Again we use Obstfeld's model and his parameter values. In the first simulation, the shock is distributed uniformly and we calculate the expected social loss under the rule, discretion and the escape-clause policy. The loss under the escape clause is calculated for each level of $\bar{u}$, the threshold value of the disturbance that triggers an attack and a devaluation. The three expected social losses are plotted in Figure 4.[22]

The vertical axis in Figure 4 is obtained by scaling the expected social loss by 1/N, where N is the amount society would be willing to pay for reducing the annual inflation/depreciation rate

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[20]In a different context, Alexius (1997) also calculates the optimal cost in an escape-clause model.

[21]We use simulation models so we can check that our results will hold up for samples about as large as quarterly World War II data sets. They do. Figures 3-6 are plotted for much larger data sets.

[22]The curve *Expected Loss, Mixed Strategy* in Figures 4 and 6 is based on:

$$E(L_{mixed}) = p(u<\bar{u})EL(u<\bar{u}) \; + \; [1-p(u<\bar{u})][EL(u>\bar{u}) \; + \; C(\bar{u})]$$

where we treat C as part of the social loss. Note that for each level of $\bar{u}$ there is a uniquely associated cost. In general, a parameter may be attached to $C(\bar{u})$, reflecting that C may not be entirely social loss.

from 10 percent to 3 percent.[23] The various expected loss magnitudes can therefore be interpreted as the amount society would be willing to pay to defend the fixed exchange rate relative to the amount it would be willing to pay to reduce inflation from 10 to 3 percent. The horizontal axis in Figure 4 is scaled to duplicate the numerical example in Obstfeld (1994), who worked with a uniform shock over the range [-.03, .03]. For Obstfeld's uniform shock, Figure 4 shows that the expected loss from discretion is always greater than the expected loss from permanently fixing the exchange rate. For a higher shock variance, the rankings can switch, however.

Inspecting Figure 4, we also see that for very low $\bar{u}$, near -.03, the expected loss from the mixed strategy is quite high - well above both the rule and discretion. As $\bar{u}$ rises, the expected loss from the mixed strategy falls. It eventually becomes less than the expected loss from discretion and finally approaches the expected loss from fixing permanently. Consequently in the Obstfeld model, using his parameter values and uniform shocks, the escape-clause policy is never optimal. By implication, the cost of abandoning the fixed exchange-rate rule should be set so high that the currency is never devalued.[24]

How general is this result? From our simulations we know that it is specific to Obstfeld's

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[23] $N = \frac{\theta}{2}(.10^2 - .03^2)$, where the weight attached to reducing price variability in the loss function is $\theta = .15$, as in Obstfeld (1994). N is constant regardless of the distribution of the shock.

[24] The cost should be set above the top horizontal line in Figure 3. The normalized cost should be set above 1.356. Thus the resource cost of defending the fixed exchange rate should be at least 136 percent of the cost of reducing inflation from 10 to 3 percent. We state the resource cost as an inequality since C may include some deadweight-loss elements in addition to the resources distributed to speculators.

parameters and to the variance of his shock It is also specific to the uniform distribution. The uniform is special because its box shape cuts off its tails, and it is in the tails that discretion (devaluation) finds its advantage.

We next simulate the model for a normally-distributed shock whose variance is equal to that in the uniform example and depict the results in Figures 5 and 6. Figure 5 is the exact counterpart to Figure 3, except constructed for normal shocks. From inspection of Figure 5 multiple equilibria are clearly possible for an intermediate range of C. While possible, are the multiple equilibria relevant when C is set appropriately?

Figure 6 plots expected social losses for the three relevant strategies: the rule (fix irrevocably), discretion (devaluation period-by-period) and the mixed strategy (devalue when the shock exceeds a lower bound, $\bar{u}$). It is the counterpart to Figure 4 but constructed for the normal distribution. What we see now is that the expected loss from the mixed strategy is no longer monotonic in $\bar{u}$. For low values of $\bar{u}$, it exceeds the loss from discretion. As $\bar{u}$ increases, the expected loss from the mixed strategy rises, reaches its maximum, and then falls to a minimum. Around the minimum, the expected social loss from the mixed strategy is smaller than the loss under the rule or discretion.

The value of C that produces the minimum expected loss for the mixed strategy shows that the resources devoted to maintaining the fixed rate should be no more than two-thirds the resource value of reducing inflation from 10 to 3 percent.[25] This value of C also produces multiple

[25] The expected social loss from the mixed strategy reaches its minimum when $\bar{u}$ = .016. The value of C for $\bar{u} = .016$ is C=.6639. The horizontal line in Figure 5 is at $\sqrt{2C} = 1.152$, where C=.6639.

solutions for $\bar{u}$, the escape-clause trigger. This result can be seen in Figure 5, where the corresponding value of this C intersects the curved line $\sqrt{2(L^R - L^D)}$ three times. This solution multiplicity (three solutions here) is the counterpart to the two internal solutions that turned up in the example with a uniformly distributed shock.

The three solution values for $\bar{u}$ are mapped into Figure 6 and give three possible expected losses for the mixed strategy at points 1, 2 and 3. The expected losses at points 1 and 2 are much greater than the loss at point 3. More important, if C is set to achieve the minimum expected loss, there is no guarantee that the economy will settle on the highest trigger value for the escape clause. Indeed, our earlier line of argument about relevant solutions suggests that the economically relevant solution - the one speculators would prefer - is the solution at point 1. Expected social loss at this solution is distinctly inferior to both the rule and discretion.

In order to avoid the solution multiplicity illustrated in Figure 5, C could be set high enough to make the solution unique. This requires that C be at level where the resources supporting the fixed exchange rate are about 80 percent of the resources used to reduce inflation to from 10 to 3 percent. At this unique solution, the annual probability of speculative attack is about 10 percent, so that expected regime duration is around ten years. In other words, fixed exchange-rate regimes will be attacked on average once every ten years. The “second-best” optimum gives an expected social loss above the loss at the (possibly unobtainable) social optimum, but the difference is small. The expected social loss of the second-best mixed strategy is less than the loss under discretion or under the irrevocably-fixed exchange-rate rule, but it is not much less than the loss under the rule.

In the optimal currency area literature that followed Mundell, choosing the appropriate exchange-rate regime often required knowing the mean and variance of the relevant shocks. The present analysis suggests that these central moments are relevant but they are not enough. In our simulations of the escape-clause model, the mean and variance of the shock are identical across the uniform and normal distributions, but the shapes of the two distributions give different policy guidance. With uniform shocks, having a speculative attack is never optimal; with the normal shocks, it is optimal to have an attack on occasion (about every 10 years on average in our numerical example). The difference in optimal attack frequencies is due entirely to the shape of underlying shock distributions. The uniform distribution has short tails while the normal one has long tails. Extreme shock outcomes are thus more likely when shocks are distributed normally. While the escape clause should never be used for the uniform shocks, it should be invoked periodically if the economy typically faces normal shocks. After all, the whole reason for the escape clause is to have a contingency for extreme events.

Our example with one real shock and a simple rule suggests an intuitively pleasing addendum to Mundell's optimal currency area principle: Holding shock variance constant, commitment to a fixed exchange rate should be inversely related to the likelihood of extreme shocks.

Section 2.2 A Suggestion for a Common Cross-Generation Framework

The first- and second-generation models we have explored differ in a variety of ways, but most of the differences can be traced to one crucial assumption: first-generation models assume the commitment to a fixed exchange rate is state invariant whereas second-generation models allow it to be state-dependent.

The assumption of a state-invariant commitment does not square well with common observations or with careful empirical work. The government's commitment to the fixed exchange rate is often constrained by such factors as unemployment, the fragility of the banking system, the size of the public debt, or upcoming elections.[26] Recognizing that these factors affect the government's ultimate commitment to the fixed exchange rate is a major contribution of the second-generation work.

In many second-generation models, the constraints on government actions enter the social loss function as explicit policy objectives. Once we interpret the cost C as (in part) the optimal degree of reserve commitment to the fixed rate, then the state variables influence that commitment as well. For example, if the output distortion (k) in the Obstfeld model depends on lagged unemployment, n_{t-1}, then the optimal C is a function of n_{t-1}. As a linearization we can write:

$$C_t = \lambda_0 + \lambda_1 \eta_{t-1} \qquad (19)$$

In the first-generation models, the government's commitment to the fixed exchange rate does not depend on such factors as the state of the business cycle. Instead, its commitment is modeled by setting post-attack international reserves, $\tilde{r}$, as a state-invariant constant, usually

[26]For example, see Obstfeld (1994) for a discussion of how unemployment or the cost of servicing the public debt can increase the pressure on the government to devalue. See Drazen and Masson (1994) for a model where persistent unemployment can increase the probability a government will devalue in the future if it chooses not to devalue when adverse shocks first hit the economy. See Calvo (1995) for a discussion of how the fragility of the banking sector constrained the decision of the Mexican government to support the peso.

zero for simplicity.[27] As a result, the post-attack reserve level enters the shadow exchange rate equation as a constant or not at all.

Instead of having the post-attack reserve level be a fixed number, suppose it is chosen optimally period by period to minimize a government loss function that includes unemployment or other objectives. In the same way that state variables affect the cost in the escape-clause model, we now have state variables affect the reserve commitment to the fixed rate:

$$\tilde{r}_t = \gamma_0 + \gamma_1 \eta_{t-1} \tag{20}$$

Where post-attack reserves were set at zero previously, they now depend on unemployment or any other state variable that influences the governments loss function.

Making $\tilde{r}_t$ endogenous implies having the government control part of the behavior of the shadow exchange rate period by period. A first-generation policy authority now has the same room to maneuver accorded in the second generation. In particular, in the basic model of Section 1, $r_t - \tilde{r}_t$ is now the maximum unsterilized intervention to be undertaken in defense of the fixed rate. The government can thus engineer the size of the attack-conditional exchange-rate jump. For example, suppose that a first-generation government faces Obstfeld's trade-off between inflation and employment and that the government's only policy tool is to pick the maximum size of the commitment to unsterilized intervention - that is, to pick the reserve level at which the fixed rate is to be abandoned. This simply amounts to letting the jump to the shadow rate replace the

[27]The reserve constant need not be an arbitrary one. Blanco and Garber (1986) and Cumby van Wijnbergen (1989) estimate the reserve level rather than impose it arbitrarily while Buiter (1987) sets the reserve constant optimally.

depreciation rate in Obstfeld's problem. The reserve commitment enters the shadow rate equation and this is the tool the policymaker uses to control the shadow rate. The period-by-period optimal reserve commitment will be influenced by the state variables in the government's choice problem. While the potential profit opportunities for speculators are still crucial to the outcome, unemployment, the fragility of the banking system and other state variables also influence the timing of currency crises.[28]

Making the commitment to the fixed exchange rate state-dependent in the first-generation model provides a potential reconciliation of first- and second-generation models. This reconciliation is attractive for three reasons:

1. It gives policymakers in first-generation models the same degrees of freedom accorded them in second-generation models.

2. It keeps interactions between speculators and the government at center stage. This focus is especially important for presenting these ideas to nonspecialist audiences. The degree of monetary policy commitment (unsterilized intervention) to the fixed rate versus other policy goals is the key for policymakers and speculators alike. It is very much in the spirit of Krugman's original probing speculators who had to guess at the reserve commitment to the fixed rate.

3. It allows the first-generation models to pick up what we think is the most important contribution of the second-generation models - state dependence of regime commitment - in a simple and intuitive way.

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[28]Buiter-Corsetti-Pesanti (1996) suggest that the shift in attitude toward exchange rate and monetary policy coordination among European policymakers triggered the collapse of the ERM in 1992. In the present context, the policy stance of partner countries would influence the optimal reserve commitment to the fixed exchange rate, the shadow rate, and hence the attack time.

There are some drawbacks, however:

1. Without reconciliation, second-generation models seemed to avoid the chronic problem of relying on a tenuous foreign-exchange market model to analyze currency crises. We think that this avoidance is an illusion, however. Speculators are an important part of speculative attacks. Modeling speculative profits seems essential to a complete story.

2. Without reconciliation, first-generation models with state-invariant reserve commitments were simple, depending only on parameters and fundamentals appearing in the money market. Adding a policy choice function adds several parameters to the shadow rate equation, but these are not literally free parameters. They should vary in predictable ways across policy choices.

Section 3. Recent Empirical Work

The currency crises of the 1990s have raised questions about whether currency crises are predictable events with systematic early warning signals or whether they are essentially unpredictable, like stock market crashes.

To the extent that speculative attacks are predictable events, recent theoretical work has expanded the list of potential market fundamentals that can predict them. Indeed, any economic objective that is conceivably part of the government's social welfare function and whose attainment involves a trade-off with the fixity of the exchange rate is a potential fundamentals candidate. Focusing on a broader set of fundamentals, including unemployment and the state of the banking system, improves our ability to predict some currency crises, but it is hard to generalize these results since the relative importance of various fundamentals can vary over time for a single country and vary across countries during a single time period.

Prior to the events of the 1990s, currency crises were thought to have a significant predictable component, with the standard first-generation models identifying fundamentals useful for prediction. A fiscal deficit financed by domestic credit creation was considered to be the root cause of a speculative attack. As the monetary authority monetized the budget deficit, it caused a gradual decline in international reserves. Eventually, investors attacked the fixed exchange rate, depleting the government's reserve holdings used for a defense. Home goods prices began rising before the attack. These price increases led to a real exchange-rate appreciation and a widening current-account deficit prior to an attack. Empirical work on pre-1990s currency crises confirmed this pattern in the data.

For example, Blanco and Garber (1986) used a variant of the Krugman-Flood-Garber model to predict the timing of devaluations brought on by attacks on the Mexican peso over the 1973-1982 period. Using a structural model, they estimated the objective probability that the shadow rate would exceed the fixed rate in the next quarter. Their probability estimates were around 2-5 percent in tranquil times but rose above 20 percent before the 1976 and 1982 devaluations. The size of the probability estimates indicates that while the devaluations were not anticipated fully, neither were they a complete surprise. Further, the rate of domestic credit growth and the standard money demand variables were important determinants of the probability of devaluation. This work was extended by Goldberg (1993). Cumby and van Wijnbergen (1989) used a similar approach and found that the growth of domestic credit was the main factor behind the attack on the Argentine crawling peg of the early 1980s.

These studies used economic models to interpret data for particular countries in specific time periods, leaving open the question about the generality of the results. Later studies, using a nonstructural approach to analyze crisis episodes in a set of countries before the 1990s, confirmed the role of traditional fundamentals in predicting crises. For example, Edwards (1989) examined the evolution of a number of key variables during the three years preceding each of 39 devaluation episodes in developing countries between 1962 and 1983. Comparing the outcomes with those from a control group that maintained a fixed exchange rate for at least ten years, he found that as the year of devaluation drew nearer, macroeconomic policies became increasingly expansive in the devaluing countries, the real exchange rate appreciated, the current-account balance declined and there was an important rundown of international reserves. Klein and Marion (1994) used panel data for 80 devaluation episodes in Latin American countries during the 1957-1991 period and found the monthly probability of abandoning a pegged exchange rate increased with real overvaluation and declined with the level of foreign assets. Structural factors, such as the openness of the economy and its geographical trade concentration, political variables, such as changes in the executive, and time already spent on the peg also influenced the monthly probability of ending a fixed exchange rate.

The speculative attacks of the 1990s, particularly those in Europe, challenged the view that currency crises were due largely to the government's inability to achieve fiscal and monetary discipline. For many countries, these crises were not preceded by overly expansionary policies. In trying to understand the origins of these recent crises, a number of researchers have turned to exploratory empirical models that use a wide variety of information variables to distinguish between periods leading up to currency crises and tranquil periods. As examples of this type of work we shall review the studies of Eichengreen, Rose and Wyplosz (1995), Sachs, Tornell and

Velasco (1996), and Kaminsky, Lizando and Reinhart (1997).[29]

Eichengreen, Rose and Wyploz (1995) (ERW) study a panel of 20 industrial countries over the 1959-1993 period. They depart from previous empirical work by constructing a definition of a currency crisis and then letting the data choose the episodes for study. ERW use the Girton and Roper (1977) idea of "speculative pressure", which is measured as a weighted average of exchange rate changes, interest rate changes and [the negative of] reserve changes. ERW then define speculative attacks as periods when this index of speculative pressure reaches extreme values.[30] In practice, ERW define extreme values to be those at least two standard deviations above the mean. They also conduct sensitivity analysis and discover that their results are "largely robust to [the] choice of weighting scheme" (ERW p. 278, fn 37).

In symbols, the ERW definition of crisis is:

$$Crisis\ \ if: \quad K_t = w_1 \Delta s_t + w_2(-\Delta r_t) + w_3 \Delta i_t > T \qquad (21)$$

where K_t is the ERW index of speculative pressure, the w_i are weights and T is the two- standard-deviation threshold.[31]

What do the attack models lead us to expect about the behavior of the pressure index, K_t? If the attack is anticipated perfectly and follows the pattern of the Krugman model literally, then at the moment of the attack international reserves drop by a discrete amount, the domestic-

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[29]We focus on only one strand of empirical work. Jeanne (1995) initiated another strand that tests for multiple equilibria.

[30] Speculative attacks are only one of the event types studied in ERW.

[31] Versions of this definition have been used by ERW (1996a,1996b), Frankel and Rose (1996), Sachs, Tornell and Velasco (1996a), Kaminsky and Reinhart (1996), and Kaminsky, Lizondo, and Reinhart (1997).

currency interest rate jumps up by the size of the expected rate of depreciation, and there is no change in the exchange rate. Thus reserves and interest rates should both jump and the pressure index, K_t, will pick up the attack.

Now relax the Krugman assumptions that the opportunity cost of holding money is given by a zero-maturity domestic-currency interest rate and that the crisis is foreseen perfectly. With a longer-term interest rate and uncertainty, the relevant interest rate will begin rising before the crisis - so reserves will leak out faster prior to the attack.[32] At the moment of attack, reserves still drop and the interest rate still jumps up, but the size of each jump is reduced to the extent the attack is anticipated. Since the crisis is only partly anticipated, the exchange rate will jump up also at the attack time. The important point is that the size of all these jumps is reduced at the attack time by the extent to which the attack is anticipated. Selecting only extreme values of K as a measure of crisis may reduce the share of predictable crises in the sample.

Next, depart from the Krugman scheme by allowing the crisis to end with a devaluation rather than with a float. Suppose further that the post-devaluation regime is expected to be stable, at least extending beyond the maturity of domestic-currency interest rates used in money demand. Then in the period leading up to the devaluation, even if the crisis is only partially anticipated, domestic-currency interest rates will rise to compensate domestic-currency bond holders for the impending devaluation. Immediately following the devaluation, however, domestic-currency

[32]Assuming domestic and foreign bonds are perfect substitutes, domestic agents react to rising interest rates by exchanging some of their domestic currency for foreign-currency denominated bonds, thereby depleting international reserves more rapidly. If domestic and foreign bonds are imperfect substitutes, then rising domestic interest rates may encourage agents to increase their holdings of domestic-currency denominated bonds. In that case, reserves might not leak out faster prior to the attack.

interest rates will fall back to the level of foreign-currency interest rates. Reserves, which flowed out of the domestic country before the crisis (because of expanding fundamentals and reduced money demand) will flow back into the domestic country to satisfy increased money demand.[33] Of course, in the event of the devaluation the exchange rate increases.

To the extent that the devaluation is anticipated, two of the three ERW indicators *point in the wrong direction* at the devaluation time. We emphasize that this analysis is not an impeachment of the ERW definition because the ERW definition does a good job at catching historical episodes that we would have classified as crises according to our prior beliefs. What it means is that if the Krugman model is correct, the ERW selection method of choosing extreme values of K predisposes the sample towards crises with significant unpredictable components.

How well does the ERW method predict crises? If crises have large unpredictable components, the pressure index K will more likely reach an extreme value, but the more unpredictable the crises, the less likely they are to be significantly correlated with the information variables selected as possible crisis determinants. Thus the empirical methods may not be able to predict these crises very well. Moreover, if the potential determinants of currency crises differ across countries and across time, panel regressions that look for consistent patterns may perform poorly.

ERW find that crises by their definition "tend to occur when unemployment is high and when political circumstances are unpropitious." We interpret their findings to mean that data-

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[33]These effects exist literally only in the Krugman model. In actual data, the analysis would be considerably clouded by time aggregation (especially for reserve flows) and by government pegging of (overnight) interest rates.

defined crises are hard to predict using standard fundamentals and panel methods.[34]

ERW try to predict currency crises in industrial countries, the same low-inflation countries for which models of exchange-rate determination perform poorly on fairly high frequency data.[35] Other empirical researchers have examined currency crises in developing countries, where larger variations in the data may help improve the predictive power of these models. Kaminsky, Lizando and Reinhart (1997) (KLR), for example, apply a version of the ERW technique to a panel of 15 developing and 5 developed countries.[36] They find that a number of variables, including traditional fundamentals, help predict crises.[37] Sachs, Tornell and Velasco (1996a) (STV) compute an ERW-

[34] Otker and Pazarbasioglu (1994) (OP) estimate the one-month ahead probabilities of a speculative attacks in five European countries during the 1979-1993 period. They find that market fundamentals do quite well statistically (in terms of coefficient significance) for many of the countries and the fitted probabilities of crisis often rise to high levels (over 50%) in the months immediately preceding crises. They also find that certain speculative proxies predict crises with reasonable accuracy. In addition, OP find that estimating their model as a panel gives quite poor predictions for the probability of devaluations. Consequently OP estimate probabilities on a country-by-country basis in the manner of the early structural models.

[35] The classic reference is Meese and Rogoff (1983). Of course, exchange-rate models are not the only disappointing ones. All asset-price models based on underlying fundamentals work poorly.

[36] The panel includes the Mexican crises in 1976 and 1982 studied by Blanco-Garber (1986), the Argentine experience in the early 1980s studied by Cumby and van Wijnbergen (1989), the 1994 Mexican crisis and the 1992 crises in Finland and Sweden. Since many developing countries did not have market-determined interest rates prior to the 1990s, the speculative pressure index for developing countries includes only reserve and exchange-rate changes. If capital controls limit reserve leakages in the period leading up to a crisis, then the pressure index may register a big jump at the attack time even if a crisis has a significant predictable component. As a result, the sample of crises for developing countries is less likely to exclude crises with significant predictable components.

[37] The KLR approach, which they term a *signals* approach, is more nonlinear than the ERW one, in that KLR determine signal thresholds for information variables as well as for crises, but it is in the same spirit. KLR find their crises to be predictable based on signals provided by exports, real exchange rates, broad money/international reserves, output and equity prices.

style pressure index variable for a sample of twenty developing countries over the 1994-95 period. STV regress the actual monthly value of the index, which excludes interest rates, on nonlinear combinations of the real exchange rate, a measure of bank-loan growth (an indicator of bank fragility) and the ratio of country M2 to reserves (an indicator of reserve adequacy). All three variables are found to be important predictors of movements in the pressure index.

The studies we have reviewed differ in sample selection methods and in the use of prior information. As is usual in international finance, developing countries (unfortunately) have much more data variance than industrial countries. Consequently, the empirical models do better at identifying variables that are significantly correlated with crises. While the empirical work on developing countries still finds an important role for traditional market fundamentals such as domestic credit growth, it goes a bit farther. In developing countries there is evidence that (1) the level of liquidity relative to reserves seems to be a good predictor of currency crises, and (2) a variety of indicators of economic conditions (eg., recessions, the state of the banking system, monetary policy, international interest rates) seem to matter for crises.

Section 4 - Conclusion

The currency crises of the 1990s have made us appreciate the fragility of fixed exchange-rate regimes. Responsibility for these crises cannot be placed entirely on the shoulders of poorly-behaved governments who pursue excessively expansionary policies. While some governments make policy mistakes and are disciplined eventually, others face hard policy choices not entirely of their own making. When speculators sense that a fixed parity is tightly constrained by other policy goals, that parity may be prone to attack.

Evidence to date reinforces the view that currency crises are not all alike (see Calvo 1995). Some crises, particularly those in developing countries, have a significant predictable component. Others may have a predictable component only in hindsight, once we broaden our notion of the fundamentals affecting the strategic interactions of governments and speculators. Still other crises are difficult to interpret exclusively on the basis of fundamentals and have led to new explanations based on informational frictions and herding behavior. We note, however, that the speculative attacks we understand least well occur in foreign-exchange markets that we understand equally poorly.

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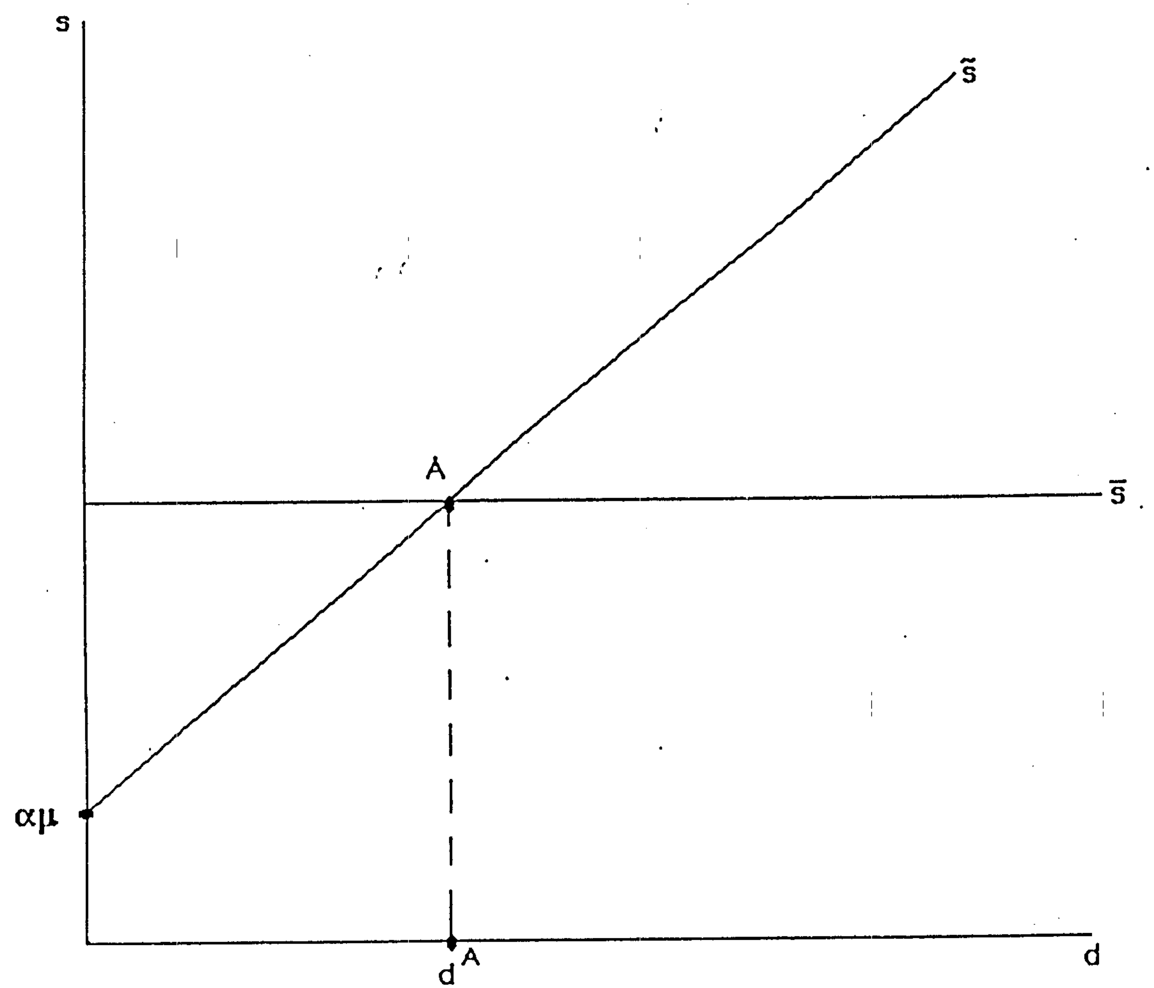

Figure 1: Attack Time in a Certainty Model

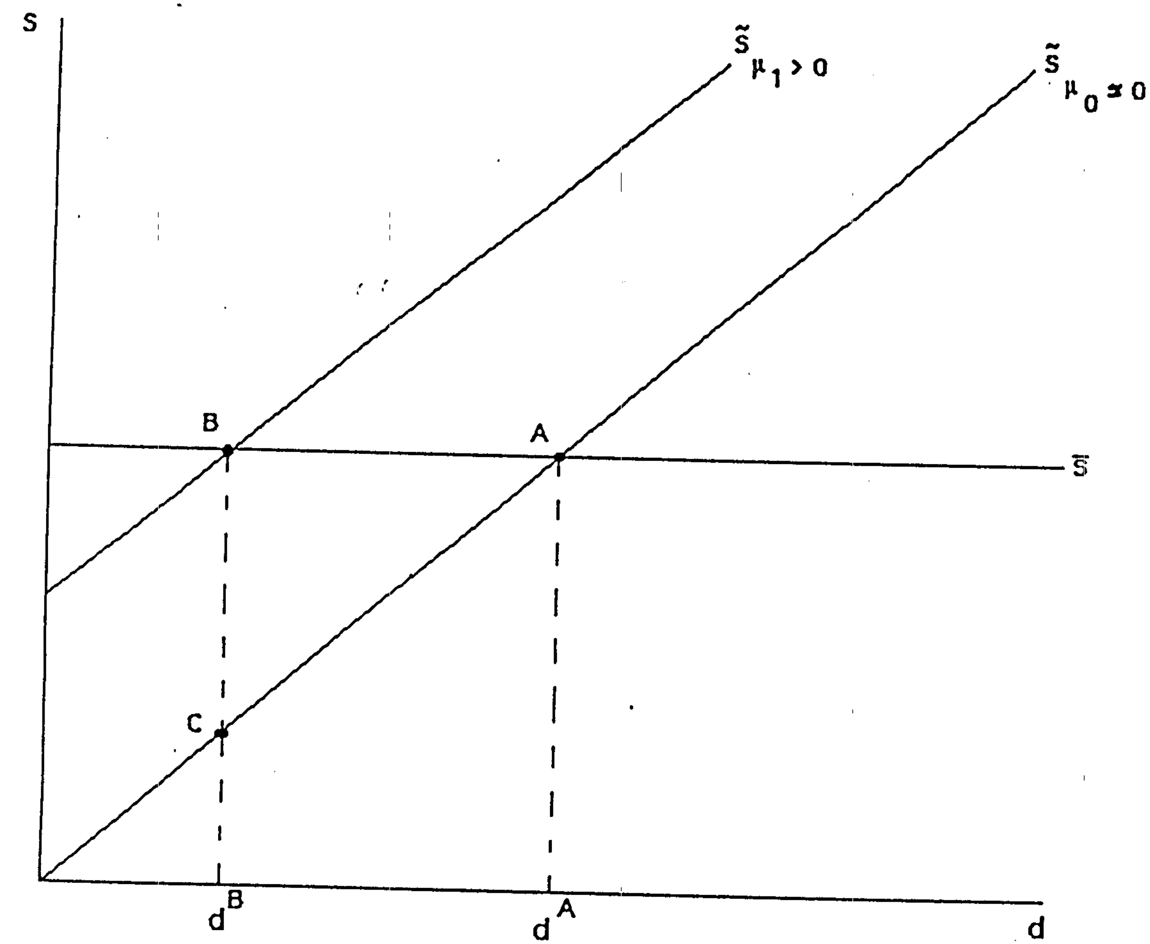

Figure 2: Attack Times with Attack-Conditional Policy Shift

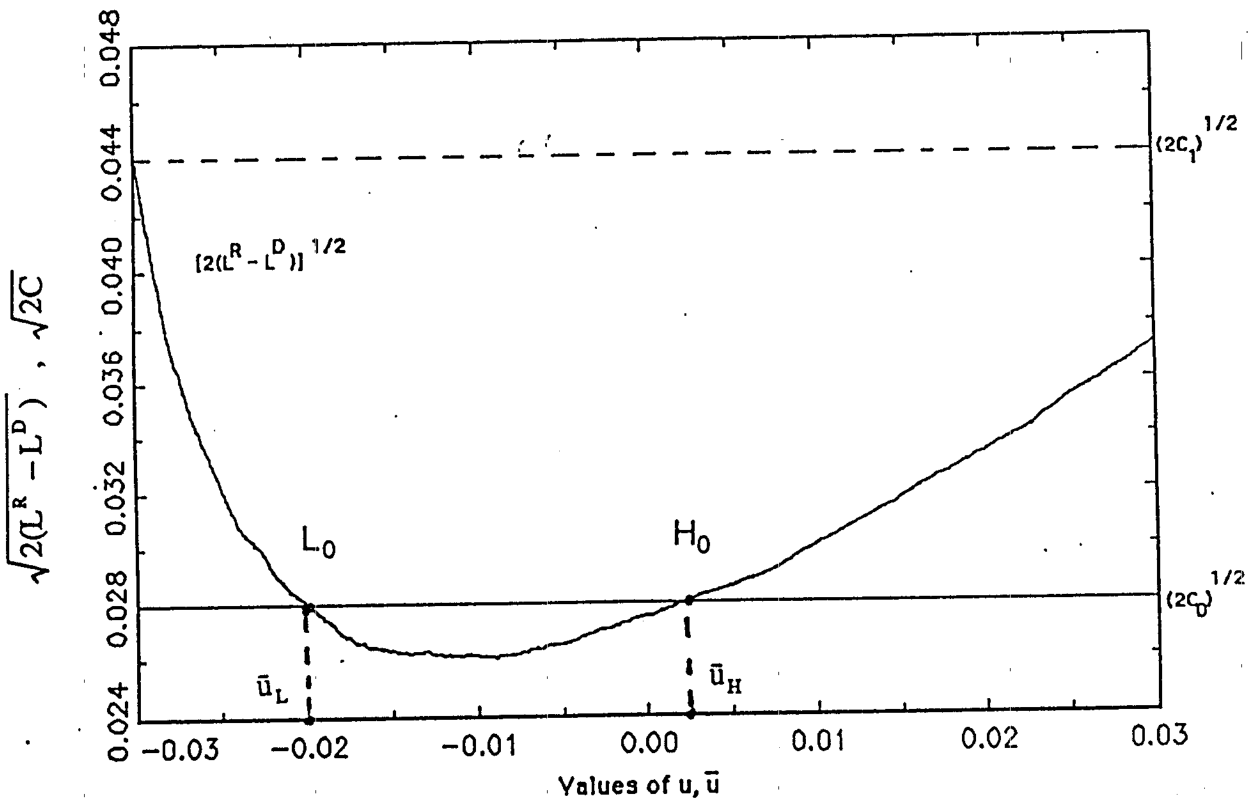

Figure 3: Multiple Solutions with Uniform Shock

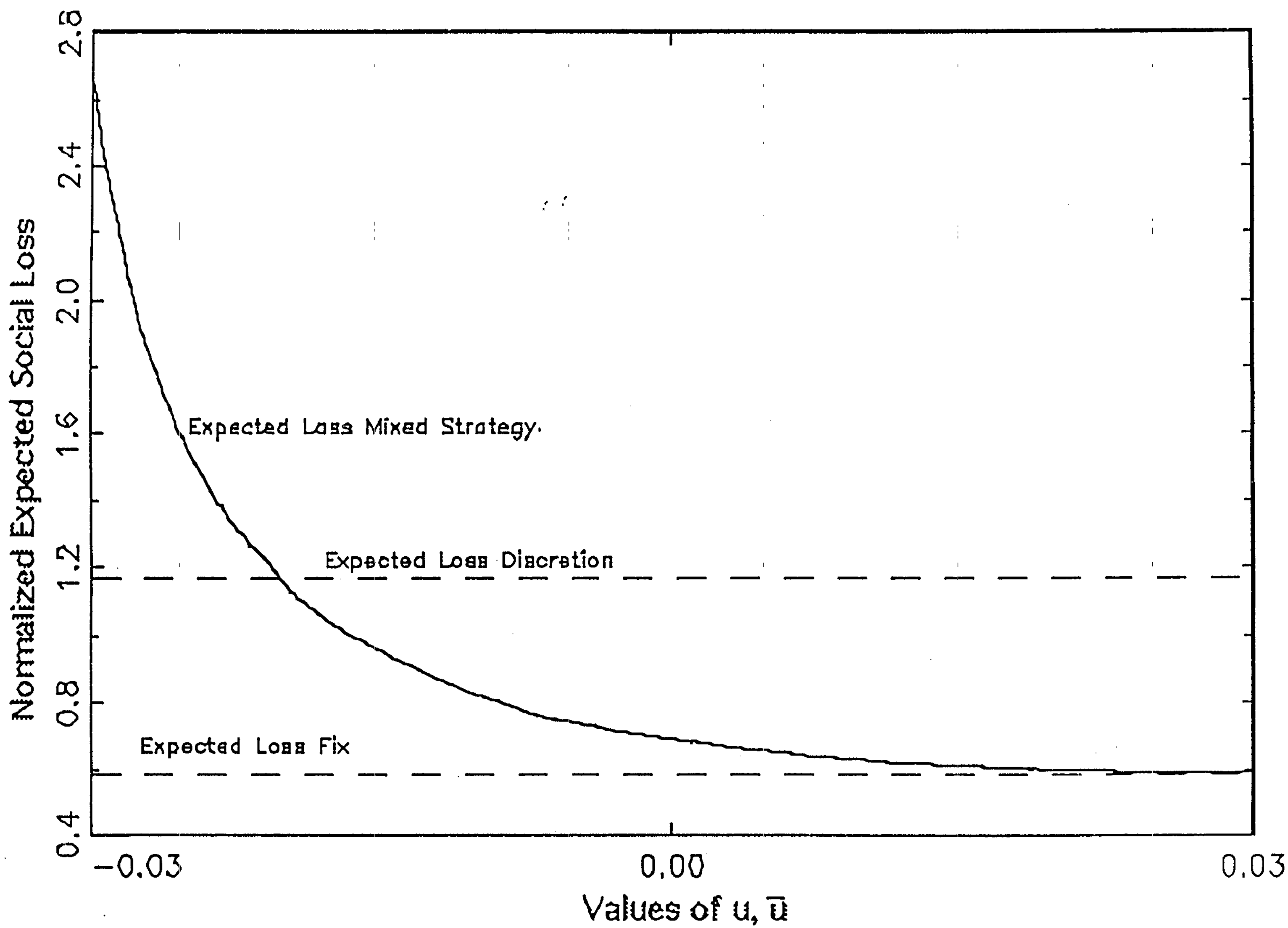

Figure 4: Expected Social Loss with Uniform Shock

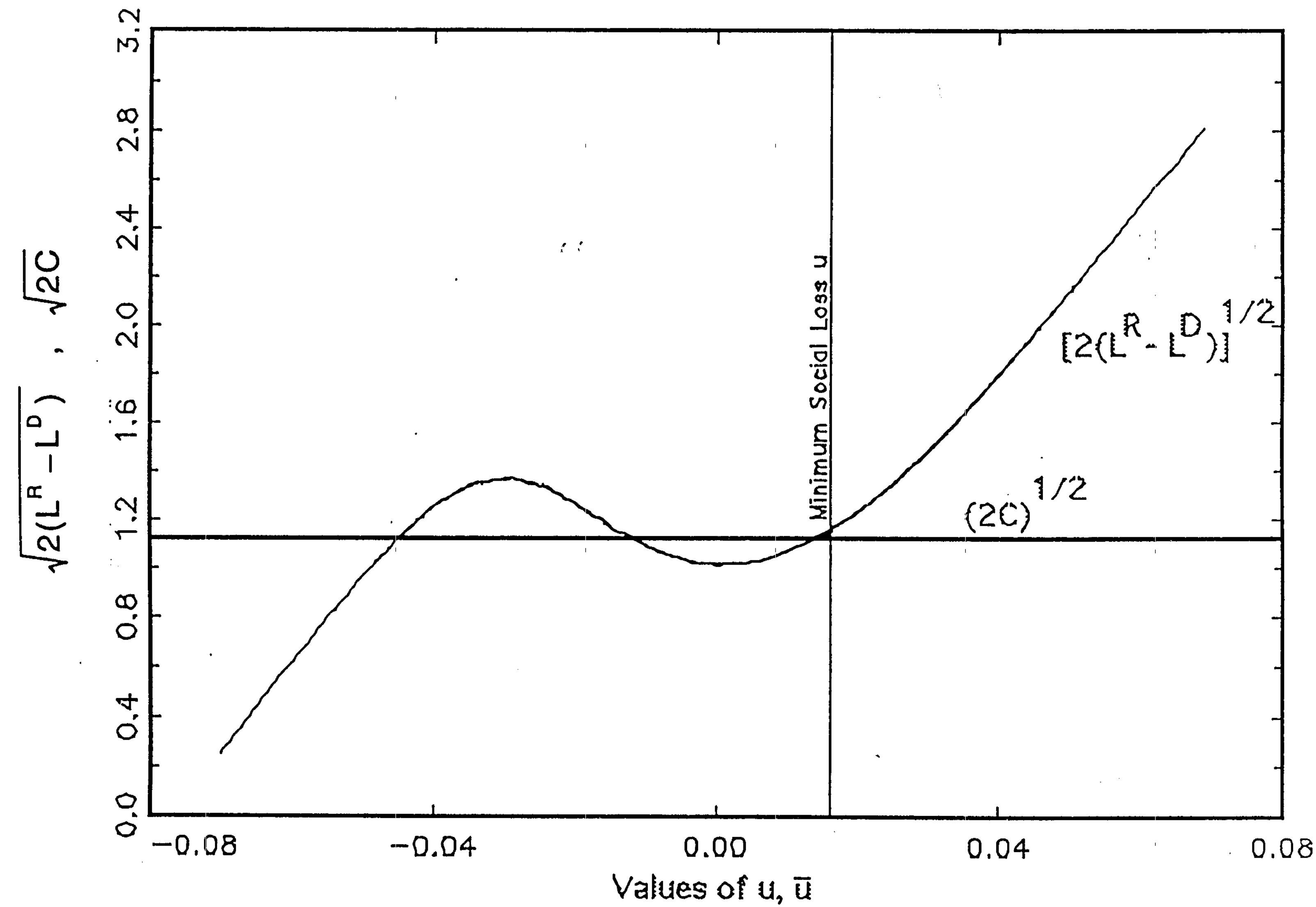

Figure 5: Multiple Solutions with Normal Shock

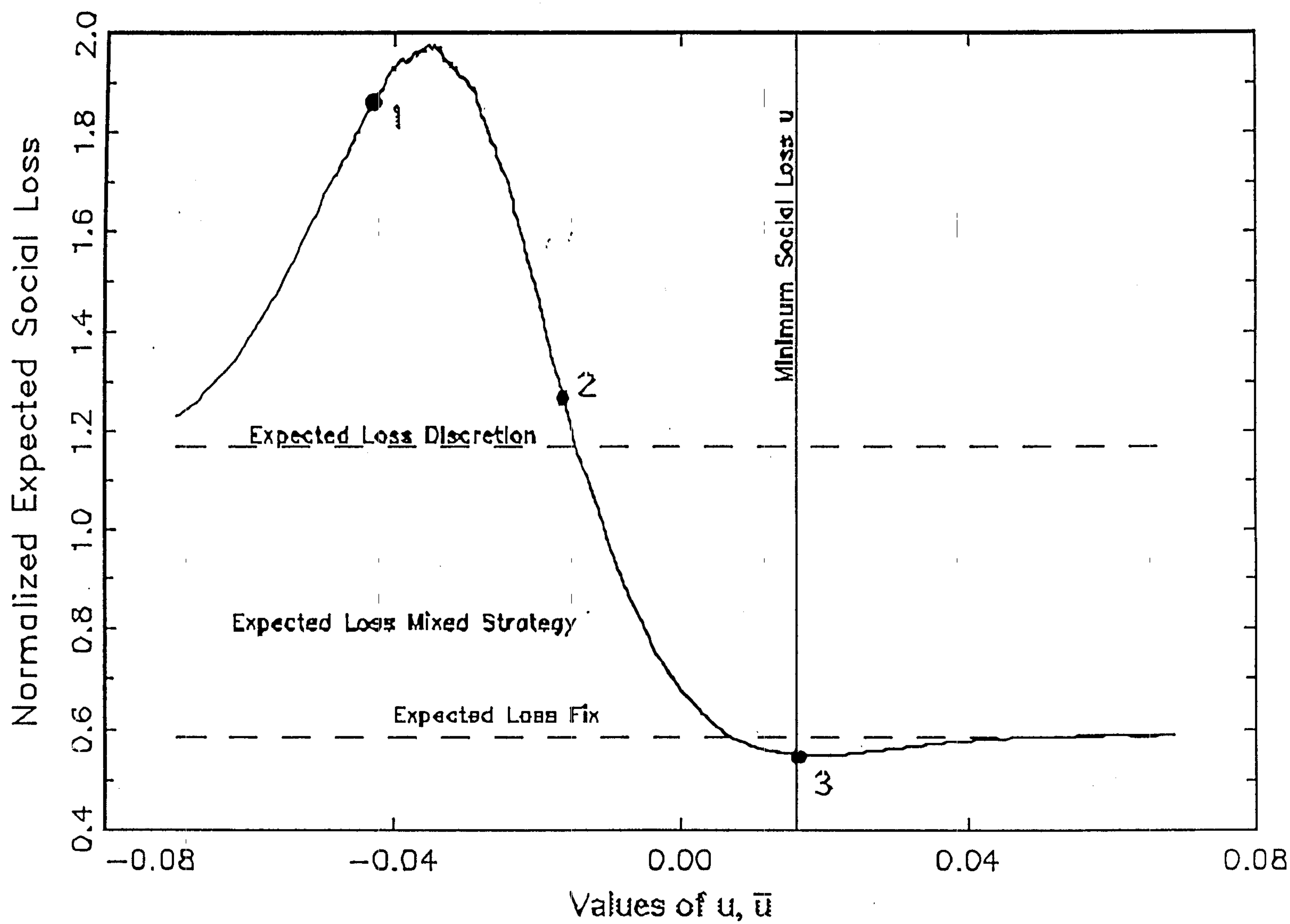

Figure 6: Expected Social Loss with Normal Shock