Contagion:
macroeconomic models with multiple equilibria

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Abstract

Several concepts of contagion are distinguished. It is argued that models that allow only a single equilibrium conditional on the macroeconomic fundamentals are not adequate to capture all forms of contagion, hence it is useful to formulate macro models that admit multiple equilibria and self-fulfilling expectations. A simple balance of payments model is presented to illustrate that phenomenon, and some back-of-the-envelope calculations assess its relevance to the coincidence of emerging market crises in 1994–95 and in 1997. © 1999 Elsevier Science Ltd. All rights reserved.

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1. Introduction

The balance of payments crises in Asia, beginning with pressures on the Thai baht and spreading to other countries in the region, have intensified the interest in models of contagion that began with Mexico’s Tequila crisis in 1994–95. As Eichengreen et al. (1996) and others have pointed out, there are many reasons for crises to be contemporaneous in time. Using a terminology proposed in a companion paper, the macroeconomic linkages behind contagion can be divided into monsoonal effects,
spillovers, and jumps between multiple equilibria (Masson, 1999). The former effects emanate from the global environment (in particular, from policies in industrial countries), and sweep over all developing countries to a greater or lesser extent. Spillover effects explain why a crisis in one country may affect other emerging markets through linkages operating through trade, economic activity, or competitiveness. The third category is a residual: if the first two do not explain the coincidence of crises, it is argued that there is a role for self-fulfilling expectations in which sentiment with respect to a given country changes purely as a result of a crisis in another country. In Masson (1999), it is argued that macroeconomic fundamentals alone do not seem to have justified speculative attacks on other Latin American countries at the time of the Tequila crisis, nor the spread of crisis from Thailand to other East Asian countries in 1997. The magnitude and timing of developments in industrial countries (such as the tightening of US monetary policy in 1994 and the appreciation of the dollar in 1995–96) cannot plausibly explain these developments. Trade and competitiveness linkages within Latin America and East Asia are not strong enough for a crisis in one country to have worsened the fundamentals significantly in others in the region. Monsoonal and spillover effects therefore do not seem sufficient to understand the spread of contagion, suggesting the need to formulate models with multiple equilibria.

It is, of course, crucial to try to understand and model how shifts in sentiment occur, and the reasons why investors may exhibit herd behavior and be subject to contagion. However, theories of fads and herd behavior tend to be very microeconomic in their focus, and sensitive to assumptions concerning informational asymmetries and the order in which agents act (Banerjee, 1992; Bikchandani et al., 1992; Lee, 1997; Morris and Shin, 1998; Chari and Kehoe, 1998). They are therefore difficult to embed into macroeconomic models that are rich enough to include the spillover and monsoonal effects. In any case, it is important to understand how differences in the processing of information and the formation of expectations can influence macroeconomic outcomes. In macroeconomic models with a single equilibrium, it seems reasonable to suppose that rational learning behavior would lead expectations to converge to that equilibrium. Unless one accepts that expectations may differ systematically from macroeconomic outcomes, then macroeconomic models need to embody the possibility of multiple equilibria, so that shifts in expectations can be self-fulfilling.

In this paper, a simple balance of payments model is presented in which multiple equilibria are made possible through the plausible channel that expectations influence interest rates on external borrowing, and hence also the likelihood that reserves will decline below a threshold level, provoking a crisis. Because of its simplicity, the model can be solved analytically to yield clear implications concerning the factors that should influence the possibility of self-fulfilling expectations. Multiple equilibria can occur only in certain ranges for macroeconomic fundamentals, implying, in particular, conditions on reserves and the level of external debt. In the relevant ranges for the fundamentals, jumps between multiple equilibria, and hence contagion triggered by a crisis elsewhere, are possible—though the actual triggering of such jumps is assumed to be stochastic.
Back-of-the envelope calculations for the fundamentals at the time of the Mexico and Asian crises are presented for emerging market countries to see if having fundamentals in the multiple equilibria region made a country more likely to suffer from contagion. While some of the results are suggestive, this criterion is not very good at discriminating between countries subject to the Asian crisis, especially since the crisis has now spread to most emerging markets.

A final section discusses possible extensions and conclusions.

2. A simple balance of payments model

In what follows, a simple two-country model is developed to illustrate the role of multiple equilibria and contagion, as well as monsoonal and spillover effects. In this model, a devaluation occurs when foreign exchange reserves approach a certain critical level (as in Krugman, 1979, or Flood and Garber, 1984). In this very simple model, there may be no trend for the fundamentals, but if the foreign debt that needs to be serviced exceeds a certain level, then shocks to the current account can be large enough to provoke a crisis. Expectations of a crisis show up in the borrowing cost paid to foreigners. Thus, the size of the stock of external debt (assumed, for simplicity, to be predetermined) is a crucial variable for the possibility of multiple equilibria, since higher interest rates by increasing debt service costs can push reserves below the level that triggers a devaluation.

2.1. The home country

The model includes two emerging market countries; the external environment (in particular, interest rates in industrial countries, \( r^* \)) are given to them. Consider first the home country (later on we will use superscript \( a \) to distinguish it from the other emerging market country, \( b \)). It has accumulated external indebtedness \( D \), paying a floating interest rate, but for simplicity there are assumed to be no new net capital flows. Up to a point that triggers a crisis, the authorities finance any current account deficit (or surplus) through changes in reserves. The source of uncertainty is shocks to the trade balance, \( T \).\(^1\) If they are large enough to cause reserves \( R \) to fall below a critical level \( R^* \) then a devaluation (by \( \delta \) percent) occurs.\(^2\) Algebraically, for liabilities in local currency, where \( S_t \) is today’s spot exchange rate (price of foreign exchange), and \( S^*_{t+1} \) is its value next period in the event of a devaluation (otherwise \( S_{t+1} = S_t \)), the ex ante (ln) return on the asset is

\[ \text{In} (S^*_{t+1}/S_t) - r^* \]

\(^1\) However, an easy extension is to make \( r^* \) stochastic, so that the risk of a rise in world interest rates raises the probability of a crisis.

\(^2\) An interesting possibility would be to endogenize \( \delta \), by making it depend on the size of the current account imbalance. However, as will be seen below, the size of that imbalance is uncertain, since it depends on the possibility of contagion: the more crises occur elsewhere, the larger the loss of competitiveness at home, and hence also the size of the needed exchange rate change.
\[ E \ln \left( \frac{1 + r_t}{S_{t+1}/S_t} \right) = r_t - \pi_t \ln(S_{t+1}/S_t) - (1 - \pi_t) \ln 1. = r_t \] (1)
\[ - \pi_t \ln(1 + \delta) = r_t - \pi_t \delta \]

Thus, risk-neutral investors demand to be compensated by an amount equal to the risk-free (foreign) rate, \( r^* \), which we will assume is constant, plus the probability of a devaluation occurring, \( \pi_t \), times the extent of the expected devaluation, \( \delta \) (in percent).\(^3\) As we will see below the probability of a crisis will also be influenced by those very same expectations, with the circularity leading to the possibility of multiple equilibria.

The change in reserves is therefore given by the following equation:
\[ R_{t+1} - R_t = T_{t+1} - (r^* + \pi_t \delta)D. \] (2)

A crisis occurs at \( t + 1 \) if:
\[ R_{t+1} - \bar{R} < 0. \] (3)

Therefore, the probability, formed at \( t \), of a crisis in period \( t + 1 \) is
\[ \pi_t = Pr_t[T_{t+1} - (r^* + \pi_t \delta)D + R_t - R < 0]. \] (4)

In considering both the Mexican and Asian crises, however, it needs to be recognized that domestic currency external debt was quantitatively not as significant as foreign currency debt. The latter is not subject to devaluation risk; interest rates on those countries’ dollar debts nevertheless rose sharply, presumably reflecting fears of default. In practice, risks of devaluation and default are linked. Devaluation increases the domestic value of foreign currency debts and makes them more difficult to repay, provoking defaults. Conversely, a default on foreign debt (as in the debt crisis of the 1980s) leads to devaluation, as the country needs to adjust to a sharp fall in capital inflows by increasing net exports.

Default on private bank or corporate debt will occur if the value of indebtedness exceeds the value of assets, which for many of the relevant institutions were heavily concentrated in domestic currency assets, while their liabilities were in foreign currency. So increased risk of devaluation leads to increased risk of domestic insolvency and default on foreign currency obligations. At the same time, any risk that domestic assets are impaired (as occurred because of excessive lending for property speculation) would affect devaluation risk because it would raise the external borrowing costs of domestic banks and corporates on their foreign currency debt via the default risk premium. Higher borrowing costs on the latter would raise balance of payments outflows and lower reserves, making a devaluation more likely, through the same circularity as embodied in Eq. (2). So default and devaluation risk are linked, and we assume in what follows that expected devaluation size and the extent

\[^3\] Implicitly, there is a market among nonresidents for these bonds that equalizes their expected return with the foreign interest rate.
of partial default are the same, a percentage \( \delta \), so that the borrowing rates on domestic and foreign currency debt move together. For liabilities in foreign currency, where \( V_{t+1}^f \) is the value in the event of a partial default (of amount \( \delta \)) next period of an asset whose current value is \( V_t \), then the ex ante (ln) return is

\[
E[\ln((1 + r_t)/(V_{t+1}/V_t))] = r_t + \pi_t\ln(V_{t+1}^d/V_t) - (1 - \pi_t)\ln(1 + \delta)
\]

Thus, the default model is formally the same as the devaluation model.

The above model, though simple, has interesting implications concerning the relationship between the possibility of multiple equilibria and the values of key variables, in particular external debt \( D \) (taken to include both domestic- and foreign-currency-denominated debt) and foreign exchange reserves \( R \). The conditions for multiple equilibria in a model isomorphic to this one have been derived by Jeanne (1997), who tested whether the French franc/deutsche mark interest differential seemed to be subject to jumps between multiple equilibria in 1987–93. Letting

\[
b_t = T_t - r^*D + R_{t-1} - R, \quad \alpha = \delta D, \quad \phi_t = E_t b_{t+1},
\]

then the model is formally identical to the one in Jeanne (1997), with

\[
\pi_t = Pr_t[T_{t+1} - r^*D + R_t - R < \pi_t \delta D] = Pr_t[b_{t+1} < \alpha \pi_t].
\]

The possibility for multiple equilibria, as in that paper, depends on the values for \( \alpha \) and \( \phi_t \). If one assumes that the innovation in variable \( b_t, \epsilon_t = b_t - \phi_{t-1} \) has a cumulative distribution function \( F \), we can write \( \pi_t \) as:

\[
\pi_t = F[\alpha \pi_t - \phi_t].
\]

In what follows, it will be assumed that \( \epsilon_t \) is normally distributed with mean zero and variance \( \sigma^2 \), and \( F_{\sigma}(.) \) will stand for its c.d.f.

Eq. (7) defines the formation of rational expectations by investors. Since both right and left sides of Eq. (7) depend positively on \( \pi_t \), there may be multiple solutions. A necessary condition for the latter (Jeanne, 1997) is that

\[
z = \frac{\alpha}{\sqrt{2\pi} \sigma} > 1,
\]

which requires that the slope of the cumulative distribution function [the right hand side of Eq. (7)] be steeper at some point than the left hand side, a 45° line from the origin. This condition can be interpreted as a condition on the size of foreign debt.

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4 The normal distribution is convenient because its c.d.f. can exhibit enough curvature such that there are multiple solutions, depending on the variance \( \sigma^2 \). However, other distributions also allow multiple equilibria.
and on the extent of default or devaluation in case of a crisis, since $\alpha \equiv \delta D$, relative to the standard deviation of shocks to the trade balance, $\sigma$. To give a numerical illustration, suppose that the time period is one year, so that $\pi_t$ refers to the probability of devaluation or default in the coming year. If the standard deviation of trade balance shocks is 2% of GDP, and the expected devaluation size is 25%, then multiple equilibria are possible if the stock of external debt exceeds about 20% of GDP. In contrast, if the stock of debt is too small or the variance of shocks to the trade balance is too large, the c.d.f. has an elongated shape with a slope that never exceeds 1, and hence only a single equilibrium exists.

Having a slope greater than unity is not sufficient for multiple equilibria, however. There is also a condition on $f_t$, which requires it to be within a certain range so that the c.d.f. on the RHS of Eq. (7) has a slope greater than unity in the region where it intersects the 45° line from the origin. This is illustrated in Fig. 1. If the fundamentals are very good ($f_t$ large), then the c.d.f. is shifted to the right and there is only one intersection, giving a low value for $\pi_t$. Alternatively, poor fundamentals shift the c.d.f. to the left, giving one (high $\pi_t$) intersection. The range of multiple equilibria is defined by two tangency conditions of the c.d.f. and the 45° line (the corresponding values for $f_t$ are labeled phimin and phimax in Fig. 1). In particular, if we let $w \equiv \sqrt{2\log z}$, then the tangency conditions can be written as defining the following range for $f_t$ where multiple equilibria are possible:

$$\alpha F_1(-w) + \sigma w < f_t < \alpha F_1(w) - \sigma w.$$  (9)
Figs. 2 and 3 plot the dependence of this multiple equilibria region on $D$ and $\sigma$ respectively (the area between the two curves is the region where multiple equilibria are possible). Inequality (9) in essence defines a range for reserves. If they are higher than a certain value, then there is very little possibility of crisis, while if they are
below a minimum, a crisis is virtually certain. In between, multiple equilibria can occur. To continue the numerical example cited above, the following table gives the values for the right and left hand sides of the inequality (9), labeled $\phi_{\text{min}}$ and $\phi_{\text{max}}$, respectively, for various values of $D$ which exceed the level of 20% of GDP, necessary for multiple equilibria. It is further assumed that the threshold level of reserves is zero, and that the expected value of the trade balance is equal to 1.25% of GDP (chosen so that it equals the product of the foreign interest rate, assumed to be 5%, and a debt level of 25% of GDP). The values $\phi_{\text{min}}$ and $\phi_{\text{max}}$ are translated into corresponding values for initial reserves, labeled $R_{\text{min}}$ and $R_{\text{max}}$, calculated as:

$$R_{\text{min,max}} = \phi_{\text{min,max}} - E(T_{t+1}) + p^sD + R$$

<table>
<thead>
<tr>
<th>$D$</th>
<th>$\phi_{\text{min}}$</th>
<th>$\phi_{\text{max}}$</th>
<th>$R_{\text{min}}$</th>
<th>$R_{\text{max}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>2.91</td>
<td>3.34</td>
<td>2.91</td>
<td>3.34</td>
</tr>
<tr>
<td>50</td>
<td>3.81</td>
<td>8.69</td>
<td>5.06</td>
<td>9.94</td>
</tr>
<tr>
<td>75</td>
<td>4.23</td>
<td>14.52</td>
<td>6.73</td>
<td>17.02</td>
</tr>
<tr>
<td>100</td>
<td>4.50</td>
<td>20.50</td>
<td>8.25</td>
<td>24.25</td>
</tr>
</tbody>
</table>

Thus (assuming as before that $\sigma = 2\%$), for $D = 25\%$ of GDP, values for the initial level of reserves between 2.91 and 3.34% of GDP permit multiple equilibria to occur. Below 2.91, only a single (high) value of $\pi_t$ would prevail, while above 3.34, a devaluation would be viewed as unlikely and self-fulfilling crises could not occur. The range of values widens considerably as $D$ rises, as indicated in the table (though an increase in $D$ also increases the lower bound below which a single high probability equilibrium would prevail). For $D = 100\%$ of GDP a range of reserves between 8.25 and 24.25% of GDP would permit multiple equilibria.

2.2. Contagion: a jump between equilibria triggered by a crisis elsewhere

So far the model has not explained which equilibrium is chosen. One approach that is convenient for estimation is to treat jumps between equilibria as being stochastic, and having a simple Markov probability structure describing the likelihood of staying in a particular equilibrium or moving to another one (as in Jeanne and Masson, 1998). For instance, once a ‘bad’ equilibrium occurs (i.e. devaluation or default), it may be reasonable to suppose that a jump back to the ‘good’ equilibrium is not straightforward—the bad equilibrium could be an absorbing state. The experience of Mexico and Thailand suggests that an attack followed by a substantial depreciation seems to have enduring effects on confidence and also on the health of financial and nonfinancial corporations that have substantial foreign currency debt. Contagion would occur when the home country jumps to a ‘bad’ equilibrium as a result of a crisis in another emerging market country.

Such a way of modeling contagion for estimation purposes, and the balance of payments model given above, are not inconsistent with various micro theories that involve the revision of expectations or detailed models of the portfolio behavior of financial institutions. For instance, jumps between equilibria could occur because of
small triggers which lead to herding behavior (Banerjee, 1992) or ‘informational cascades’ (Bikchandani et al., 1992) or ‘avalanches’ (Lee, 1997). Or, as discussed above, a crisis in one country might lead to a reassessment of the fundamentals in others (a ‘wake up call’ as in Goldstein, 1998). However, the micro theories need to be placed in a macroeconomic context, otherwise it is difficult to understand the severity of crises affecting the real economies of Latin America and East Asia in recent years, and why euphoria and pessimism in financial markets seem to be self-sustaining for extended periods. Rational learning of a single equilibrium would suggest in contrast that market sentiment should converge to the ‘correct’ view, and that the problems of Mexico and the subsequent Tequila crisis in 1994–95 would have made investors permanently wary of countries with large short-term external exposure. While Mexico’s growth of GDP recovered quickly, serious banking sector problems have persisted, highlighting the deficiencies of supervision and regulation in many developing countries. Instead of learning these lessons, foreign investors in 1996 sent a record volume of capital flows to developing countries, and this continued into 1997, only to be abruptly reversed when the Thai baht depreciated early in July.

The model presented above, though not providing a theory of jumps between equilibria, has something to say about vulnerability to contagion. Multiple equilibria, and hence attacks triggered by crises elsewhere that go beyond the macroeconomic fundamentals (which themselves are influenced by monsoonal effects and spillovers) can occur only in certain ranges of the fundamentals. Vulnerability is greater when there is a large (floating rate) debt, when reserves are low, and when the trade balance is in deficit.

2.3. Links with other emerging markets

We now make more explicit monsoonal and spillover effects, and in particular introduce interactions between the home country \((a)\) and emerging market economy \(b\), through competitiveness effects on trade. For simplicity we will assume that all structural parameters are the same in the two countries, and omit superscripts for those parameters.

The home country trade balance is assumed to depend on the logarithm of the real exchange rate (RER), which gives a weight \(w\) on country \(b\), \(x\) on the United States, and \(u \equiv (1 - w - x)\) on the rest of the world. Nominal exchange rates \(S^a_t, S^b_t, S\) (the rest of the world’s exchange rate, assumed fixed) are expressed as the dollar price of local currency, so that an increase in \(S\) (and in RER) is an appreciation. It is assumed that the currencies of \(a\) and \(b\) are, at least initially, pegged to the dollar. Prices are assumed fixed so that nominal devaluation produces an improvement in competitiveness. The equations for the trade balance and the real exchange rate are as follows:

\[
T^a_t = T - \beta \text{RER}^a_t + \epsilon^a_t \tag{11}
\]

\[
\text{RER}^a_t = S^a_t - wS^b_t - uS_t \tag{12}
\]

Similar equations exist for country \(b\).
Now the assessment of the probability of devaluation is more complicated, since it depends on the possibility of devaluation for country $b$, captured through $p_b$. In particular, in place of Eq. (6), the probability of $R_a^{t+1} < R$ will be different depending on whether or not $b$ is expected to devalue (by $d$) next period:

$$p_a = (1 - p_a^t)Pr_a\{T - \beta(S_a - wS_b - uS_l) + \epsilon_a - (r^* + \pi_a^t\delta)D_a^u + R_a^t - R < 0\} + \pi_b^tPr_a\{T - \beta(S_a^t - wS_b^t + w\delta - uS_l) + \epsilon_a - (r^* + \pi_a^t\delta)D_a^u + R_a^t - R < 0\}. \quad (13)$$

The model illustrates the three channels by which crises can coincide in time. Monsoonal effects can take the form of a change in $r^*$ (e.g. US interest rates), or $S_t$ (e.g. the dollar–yen rate). Spillovers can take the form of changes in the initial level of the exchange rate of country $b$. The third channel works through the possibility of self-fulfilling expectations for $\pi_a^t$, since the latter variable also appears on the RHS of (13). The potential for contagion will also be affected by the expectation of devaluation in $b$ ($p_b^t$), which will have a direct effect on $p_a^t$; it can feed back onto itself through an equation analogous to (13) for country $b$.

As discussed above, the range ($\phi_{\min}$, $\phi_{\max}$) within which multiple equilibria are possible is determined by points of tangency with the 45° line from the origin. However, instead of Eq. (7) above, we now have a linear combination of it and a curve that is shifted to the right, by the amount of potential loss in competitiveness due to the possible devaluation of the currency of country $b$, $\beta w d$:

$$\pi_a^t = (1 - \pi_a^t)F_a(\alpha^a \pi_t - \phi_t^a) + \pi_b^tF_a(\alpha^a \pi_t - \phi_t^a + \beta w d), \quad (14)$$

where now $\phi_t^a = T - \beta(S_a^t - wS_b^t - uS_l) - r^*D_a^u + R_a^t - R$ and $\alpha^a = \delta D_a^u$.

Fig. 4 plots solutions to Eq. (14), for $D = 25\%$ of GDP, $\beta w = 0.1$, $\delta = 25\%$, and either $\pi_a^t = 0.2$ or 0.5. Relative to the original curve (labeled ‘without contagion’ in Fig. 4), Eq. (14) is shifted up further on the left side of the figure than on the right. As a result, both the upper and lower equilibria will involve a higher value for $\pi^a$ than when $\pi^a = 0$, but the lower equilibrium (if there are multiple equilibria) will be more affected.\footnote{It is also possible that $\pi^b > 0$ would give two points of inflection to the RHS of Eq. (14), increasing the number of equilibria for $\pi^a$. This possibility was not relevant here, given the range of numerical values assumed.} Though points of tangency (determining $\phi_{\min}$ and $\phi_{\max}$) are not shown, this suggests that the value of $\phi_{\min}$ (this is the lower tangency point) will be more affected than $\phi_{\max}$ (corresponding to the upper tangency point), because the curve needs to be shifted more in the horizontal direction to compensate for contagion from country $b$. Numerical solutions confirm this intuition.

However, there is another possibility, shown for $\pi_a^t = 0.5$, namely that the fear of a devaluation in $b$ will eliminate the multiple equilibria region entirely in $a$, and produce a single, high value of $\pi_a^t$ indicating that a devaluation is very likely. We
would still characterize this as contagion, since it is the fear of a crisis in $b$ that triggers a crisis in $a$, not spillover effects per se.

Fig. 5 pursues the relationship between devaluation expectations in $a$ and $b$, by calculating $\pi_a^t$ as a function of $\pi_b^t$ and vice-versa. If there is only a single equilibrium,
then that is plotted, but for values where multiple equilibria exist, both the upper and lower intersections (as in Fig. 4) are plotted (the middle equilibrium, which is unstable, is ignored). In this example (unlike in Fig. 4), the fundamentals $\phi^a_t$ are good enough in the absence of contagion effects that there is only a single equilibrium (as long as $\pi^a_t < 0.58$). It can be seen that in this case, in which the countries are assumed identical, an equilibrium where the probability of devaluation in both $a$ and $b$ is roughly zero is possible: in the absence of fears of devaluation in the other country, each would not be vulnerable to self-fulfilling attacks. However, above $\pi_t = 0.58$ for the other, each country is in the range of multiple equilibria. Therefore, attacking both countries’ currencies would also be rational, and two other equilibria are possible: one with $\pi^a_t = \pi^b_t = 0.58$, and a second where $\pi^a_t = \pi^b_t = 0.99$ (see Fig. 5). Thus, contagion effects amplify the possibility of self-fulfilling attacks in this model. Even if each country separately is not subject to multiple equilibria, together they may be, since the fear of crisis in one will increase the devaluation probability in the other, making a crisis more likely in both.

3. Applicability to the Tequila and Asian crises

We now turn to some simple calculations to see whether the fundamentals of emerging market countries at the end of 1994 and 1996 were such that the balance of payments model implies that multiple equilibria were possible. In assessing the possible relevance of the model we need to face whether the debt stock should be limited to domestic currency debt held by foreigners, all external debt, or all debt held by domestic and foreign residents. We choose the intermediate measure, since the model focuses on the overall balance of payments and the link between devaluation and default discussed above suggests that the broader measure of external indebtedness, in all currencies, would be the appropriate one. Another important question is whether to distinguish between short-term and long-term debt. Presumably, the measure should include that debt which comes to maturity within the horizon over which $\pi_t$ is calculated, but should also include the interest service on longer term debt. In addition, any debt which is callable by the creditor should also be included in $D$. In practice, available classifications refer to original term to maturity and do not take account of call features. We therefore include both short- and long-term debt. Limiting $D$ to short-term debt would narrow the implied region for multiple equilibria, so that the calculations that follow may, if anything, overstate the scope for such contagion.

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6 Another approach, adopted in their theoretical modeling by Sachs et al. (1996), is to consider domestic currency debt, regardless of whether it is held domestically or abroad. However, it seems clear that the Asian crisis, at least, had an important external dimension, and most external debt was in foreign currency.
Table 1 summarizes some of the relevant data for the end of 1994 and the end of 1996, the latest full years preceding the crises in Mexico and East Asia. We use the simplest version of the model to see whether it implies that multiple equilibria were possible [using Eq. (4) above]. The model suggests that a composite fundamental, called $f_t$, needs to be in a certain range for multiple equilibria to occur. The fundamental depends positively on the level of reserves and the expected trade balance, and negatively on the stock of debt and the foreign interest rate. The calculation assumes that the threshold level of reserves, $R$, is zero; that is, a devaluation does not occur until reserves are completely exhausted. This is unrealistic, and a positive value for this threshold level would tend to reduce the values of $f_t$ calculated below.

The possibility for multiple equilibria also depends on the value for $z_t$, which in turn depends on the debt, the size of a potential devaluation $d$, and the variance $s^2$ of innovations to the trade balance—as does the range for $f_t$ within which multiple equilibria are possible. In implementing these calculations, for each country a first-

<table>
<thead>
<tr>
<th>Country (σ)</th>
<th>Date</th>
<th>$D_t$</th>
<th>$R_t$</th>
<th>$T_t$</th>
<th>$z_t$</th>
<th>$f_{\min}$</th>
<th>$f_{\max}$</th>
<th>$\Phi_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina (2.12)</td>
<td>1994</td>
<td>31.9</td>
<td>5.1</td>
<td>-2.5</td>
<td>1.51</td>
<td>3.38</td>
<td>4.62</td>
<td>1.93*</td>
</tr>
<tr>
<td></td>
<td>1996</td>
<td>34.4</td>
<td>6.1</td>
<td>-0.3</td>
<td>1.60</td>
<td>3.47</td>
<td>5.03</td>
<td>4.71*</td>
</tr>
<tr>
<td>Brazil (1.69)</td>
<td>1994</td>
<td>28.0</td>
<td>6.6</td>
<td>1.1</td>
<td>1.65</td>
<td>2.80</td>
<td>4.20</td>
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<tr>
<td></td>
<td>1996</td>
<td>28.0</td>
<td>7.8</td>
<td>-1.8</td>
<td>1.65</td>
<td>2.80</td>
<td>4.20</td>
<td>5.83</td>
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<td>Chile (3.05)</td>
<td>1994</td>
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<td>25.1</td>
<td>1.4</td>
<td>1.51</td>
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*Fundamental is below multiple equilibria region, i.e. in crisis region.
*aInside region of multiple equilibria.
order autoregressive process was estimated for the trade balance as a percent of GDP, with innovations assumed to be normally distributed, and the standard error of estimate of this regression (over 1980–96) was the estimate of $\sigma$. The US one-year rate on Treasury securities was used as the foreign interest rate, $r^*$. Data for reserves, debt, and the trade balance, all as ratios to GDP, are given in Table 1. It is hard to gauge ex ante devaluation expectations, but it was assumed that the expected devaluation size $\delta$ was 25%. This is much smaller than ultimately occurred in Mexico and several Asian countries, but roughly the extent of initial currency adjustments. A larger value for $\delta$ would increase the value of $z$ and the range $(\phi_{\min}, \phi_{\max})$.

It is interesting that in most, but not all, cases, there is a range of values for $\phi$, for which multiple equilibria can occur: that is, $z$ is generally greater than unity as a result of substantial foreign debt. The exceptions are Korea and South Africa, which have relatively low external indebtedness, giving values for $z$ that do not allow multiple equilibria. Neither of them was significantly affected by the Mexican crisis. Korea was strongly affected by the Asian crisis, though relatively late, while South Africa was not.

Nevertheless, the value of the fundamental $\phi$, which reflects among other things the level of reserves, was not in all cases in the multiple equilibria region. Brazil, Chile, Colombia, and Malaysia, though admitting of multiple equilibria, had fundamentals above the admissible range in which they are predicted to occur, mainly because their reserve levels were high. Of these latter countries, only Malaysia was significantly affected by the 1997 crisis, while though Brazil was subjected to the 1994–95 ‘Tequila effect,’ it did not suffer the loss of confidence experienced by Mexico. Thailand also belongs in this latter group on the basis of the end of 1996 data, but subsequent intervention changed the picture markedly, especially when forward commitments are taken into account, with net reserves falling close to zero in June 1997. Mexico, interestingly enough, has a value at the end of 1994 for $\phi$, that is so low that it implies a very high probability of a crisis (essentially because reserves were so low and the trade deficit large), but by 1996 its fundamentals had put it in a much more favorable position (though still in the multiple equilibria region). The Philippines and Turkey are estimated to have fundamentals that imply in both years a high probability of crisis, which would be consistent with high interest rates on their borrowing.

The results are suggestive that contagion effects were possible at the time of the 1994–95 and 1997 crises, though it does not in any way test for contagion. The model has implications for the vulnerability to jumps between equilibria, but does not explain how or why they occur. The pervasiveness of contagion, however, makes it plausible that vulnerable countries would be attacked. In partial confirmation of the model, the countries spared the worst effects of crisis generally come out well in terms of the fundamentals identified by the balance of payments model as being important. This is true of such countries as Brazil, Chile, and Colombia. Korea and

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7 Brazil, like a number of other countries, was also subjected to speculative pressures following Russia’s failure to service its debts in August 1998.
Malaysia, in contrast, should have been immune to multiple equilibria when considered in isolation, suggesting that other factors came into play. In particular, Korea’s crisis may be better modeled as a Diamond and Dybvig (1983) bank run, where concerns about liquidity and access to foreign exchange, in the presence of government guarantees which were not viewed as credible, led to a loss of confidence of foreign investors.

4. Conclusions

In considering the phenomenon of contagion and what to do to limit it, it is important to understand its causes and the linkages through which it operates. There are some aspects of contagion that seem hard to explain on the basis of macroeconomic fundamentals. This suggests that it may be useful to formulate models that do not imply a unique equilibrium mapping between those fundamentals and crisis expectations. In this paper, a simple balance of payments model allowing for self-fulfilling devaluation or default expectations is presented. The model has clear implications for the range of fundamentals (principally reserves and external indebtedness) where changes in such self-fulfilling expectations—perhaps triggered by a crisis elsewhere—are possible.

In several respects the model deserves elaboration, and more complicated models would no doubt not have such stark implications for the ranges of the fundamentals where countries are vulnerable to contagion. Greater attention should be paid to financial intermediation (Agenor and Aizenman, 1997; Kaminsky and Reinhart, 1996), bank runs (Diamond and Dybvig, 1983), the maturity of government debt (Cole and Kehoe, 1996), rollover risk (Calvo and Mendoza, 1996), the role of government guarantees on deposits and private foreign borrowing (Dooley, 1997), self-fulfilling expectations of volatility (Flood and Marion, 1996), and moral hazard issues. The absence of consideration of these linkages may help to explain why the range of fundamentals implied by the model is not completely successful in discriminating between countries strongly affected by recent crises and those (mainly) spared.

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References


