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**Working Paper**

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Claremont Colleges Working Papers in Economics, No. 2000-25

**Provided in Cooperation with:**

Department of Economics, Claremont McKenna College

*Suggested Citation:* Nitithanprapas, Ekniti; Willett, Thomas D. (2000) : A Currency Crises Model That Works: A Payments Disequilibrium Approach, Claremont Colleges Working Papers in Economics, No. 2000-25, Claremont McKenna College, Department of Economics, Claremont, CA

This Version is available at:

<https://hdl.handle.net/10419/94645>

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## **A Currency Crises Model That Works: A Payments Disequilibrium Approach**

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### **Abstract**

The rash of international financial crises in the 1990s have stimulated great interest in models to predict crises and explain the patterns of contagion that follow crisis. In both of these respects analysis of the Asian crisis has proven to be quite controversial. While some economists have argued that the Thai crises should have been quite predictable based on the similarities between Thailand's situation and that of the Mexican crisis two years prior, see, for example, Salvatore (1999), other economists have argued that the Thai crisis was not predictable on the basis of the then available research, see, for example, Furman and Stiglitz (1998). Likewise some leading economists have argued that the pattern of contagion following the Thai crisis cannot be explained by rational economic models.<sup>1</sup> As a consequence they point to self-fulfilling and/or destabilizing speculation, rather than economic fundamental as the primary causes of the Thai crisis and subsequent international financial contagion.

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<sup>1</sup> Unfortunately as yet there is no general agreement in the literature on the meaning of contagion. Some use it to mean the spread of speculative attacks unjustified by the fundamentals, while others such as Eichengreen et al. (1996) use it in a more neutral sense that a crisis in one country increases the probability of a crisis in other countries, whether justified by economic and financial interdependence and rational reevaluations of countries prospects or due to herding behavior. We use contagion in their neutral sense and refer to pure contagion as contagion not justified by plausible expectations about fundamentals. For a useful discussion of different concepts of contagion see Masson (1999).

There has also been considerable disagreement in the literature about the roles of real exchange rate appreciation and current account deficits in generating crisis and influencing the pattern of their spread across countries. Some authors have found the exchange rate variable significant and the current account variable not (for example, Sachs, Tornell and Velasco (1995) and Kaminsky et al. (1998)), others find more support for current account variables (for example, Berg and Pattillo (1999a and b) and Bussière and Mulder (1999)), while still others find little support for either (Furman and Stiglitz (1998)). Furthermore, it is not uncommon to assume that exchange rate and current account variables carry essentially the same information (see, for example, Kaminsky et al (1998) and Salvatore (1999)).

We argue, however, that exchange rate and current account variables should be considered in relation to one another. In general, the past statistical work on crises prediction and explanation has been insufficiently theoretically motivated. Typically these models take a large number of variables that theory suggests may be associated with crises and put them independently into a regression, but we should be able to improve on this. International currency crises should be due primarily to actual or incipient balance of payments disequilibrium. Many different factors can cause balance of payments problems. The key to understanding balance of payments disequilibrium is recognition that it results from interrelations among variables that fail to provide equilibrium.

It is only in terms of their interrelationships with other variables that we would expect most factors to be robustly related to serious balance of payments disequilibrium and international currency crisis. Thus, for example, a current account deficit can be the

result of an overvalued exchange rate in which case there is serious potential for crisis or it can be due to large inflows of foreign direct investment in which case there is much less cause for concern. This paper presents initial efforts to operationalize this approach by developing and testing several composite variables designed to capture important aspects of whether the interrelations among these variables are in approximate balance or not. Our statistical results suggest that, unlike the Furman-Stiglitz exercise, the use of composite variables that relate substantial current account deficits to the behavior of real exchange rates and rates of foreign direct investment have considerable explanatory power with respect to the patterns of contagion following both the Mexican and the Thai crisis.<sup>2</sup> This presents a strong counter to the allegations that economists have had to come up with a new theory after each recent international financial crises and implies that the fundamentals have mattered much more than many critics of the behavior of international financial markets have posited.

### **Empirical Studies on the Severity of Crisis**

A number of different approaches have been taken to the empirical study of the statistical correlates and predictor of currency crisis.<sup>3</sup> While some studies have sought to predict the timing of crisis, other have investigated to what extent economic and financial variables can help explain the pattern through which crisis spread from one country to another. Our focus is on this later question. The initial contribution to their literature

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<sup>2</sup> Since this paper was begun, papers by Berg and Pattillo (1999a and b) Bussière and Mulder (1999) Corsetti, Pesenti, and Roubini (1999) and Tornell (1999) have also found that fundamentals have explanatory power for the pattern of contagion during the Asian crisis. Corsetti et al. use a combined measure for the exchange rate and current account that is quite similar to ours.

<sup>3</sup> For recent contributions and surveys of the literature see Berg and Patillo (1999a and b), Bussière and Mulder (1999), Goldstein and Reinhart (1999), and Kaminsky et al. (1998).

was a highly influential paper by Sachs, Tornell, and Velasco (1995). These authors analyze which countries were vulnerable to currency attacks as a result of the 1994 Mexican Peso crisis by testing a cross-section of 20 emerging countries.<sup>4</sup> They regress a crisis index, the variance-weighted average of the percentage change in the nominal exchange rate and international reserves<sup>5</sup>, on three fundamental factors: real exchange rates, banking fragility proxied by a percentage change in the bank loans to the private sector, and a ratio of M2 to international reserves.

The authors argue that international investors try to avoid short-term capital losses and flee from countries in which the investors expect a large depreciation or devaluation in the near future. Therefore, the magnitude of an exchange rate change would depend on the degree of initial real exchange rate appreciation. The more appreciated the real exchange rate, the higher the chance of depreciation or devaluation. In addition, the ability of a government to defend on exchange rate depends on the health of the local banking system. The weaker the banking system, the more unwilling the government is to defend the currency by increasing interest rates that would weaken the banking system and the more likely the government would be to devalue the currency. Lastly, since a capital reversal can be met by running down international reserves, the lower are the international reserves, the greater the chance of exchange rate devaluation. Furthermore, the authors indicate that a country with real exchange rate appreciation and banking problems would suffer a severe crisis only if the country has both weak fundamentals and

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<sup>4</sup> The list of countries is Argentina, Brazil, Chile, Colombia, India, Indonesia, Korea, Jordan, Malaysia, Mexico, Pakistan, Peru, Philippines, South Africa, Sri Lanka, Taiwan, Thailand, Turkey, Venezuela, and Zimbabwe.

<sup>5</sup> In their original development of a crisis index Eichengreen, et al (1994) (1995) also include the interest rate, but sufficient high quality data is not available to include this for developing countries.

low international reserves. Weak fundamentals are defined as when the real exchange rate appreciation and the growth in the bank loans are in the highest three quartiles of the sample.<sup>6</sup> Low international reserves are defined as when the ratio of M2 to foreign reserves is in the highest three quartile of the sample.<sup>7</sup> The Sachs et al. model find that real exchange rate appreciation and lending booms have positive effects on the crisis severity in countries with low international reserves and weak fundamentals, and do not have significant effects in countries with low reserves and strong fundamentals.

Furman and Stiglitz (1998) apply the Sachs, Tornell, and Velasco approach using data from 1997 to explain the severity of the East Asian crisis. Furman and Stiglitz's samples include 34 emerging countries, 14 more than Sachs et al. used.<sup>8</sup> The authors find that only the coefficient for lending booms in a country with low international reserves and weak fundamentals is significant and of the correct sign. The coefficient of real exchange appreciation in a country with low international reserves and weak fundamentals is marginally significant but of the wrong sign. This implies that the real exchange rate appreciation plays a very small role in the severity of crisis and that, if anything, it would decrease the severity of crisis instead. The R-squared is only 5 percent and the adjusted R-squared is -16 percent. The authors interpret these weak empirical results as showing that "the East Asian crisis was a novel event" and could not be explained by declining macroeconomic fundamentals (p. 49).

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<sup>6</sup> Several authors have questioned the use of rankings within a sample or opposed to absolute measures. See comments by Furman and Stiglitz (1998) and comment by Cooper on Sachs et al (1996).

<sup>7</sup> In regards to the definition of "low reserves" and the definition of "weak fundamentals", it might be better to label them as the absence of high reserves and the absence of strong fundamentals.

<sup>8</sup> The addition 14 countries are Bangladesh, Botswana, China, Cote d'Ivoire, Ecuador, Egypt, Ghana, Israel, Kenya, Mauritius, Morocco, Singapore, Trinidad and Tobago, and Tunisia.

One of the reasons that studies have found quite different results on the significance of real appreciation is that calculations for this variable have differed widely. This is due to differences in the base periods used, the number of currencies included in the index, and the method of calculation. The variations in these calculations across studies for the Asian crisis have been particularly large for Argentina (ranging from +18.7 to -2.3) Indonesia (from +9.6 to -10.00).<sup>9</sup> While not changing signs, calculations for China ranged from -7.0 to -35.9 and for Hungary from 0.0 to +31.4. The calculations for Thailand were much more tightly bunched, ranging from +5.5 to +7.2. Malaysia ranged from +4.5 to +11.3 while the Philippines ranged from +11.9 to +28.4.

Berg and Pattillo (1999a ) rerun the Sachs, Tornell and Velasco regression for the Mexican crisis with the same sample as the Sachs et al. study, but using the revised data currently available for that period. Berg and Pattillo find that the revision of the data changes the estimated results from those of the original paper. In particular, the estimated coefficient of the real exchange rate appreciation with weak fundamentals and low international reserves is no longer statistically significant.<sup>10</sup> They conclude, “[t]he fragility of the STV [Sachs, Tornell, and Velasco] results with respect to the data revisions that have taken place since their estimations...casts some doubt on the usefulness of this specification for the Asian crises” (p.121). However, the fit of the model remains quite substantial. In addition, Berg and Pattillo apply the Sachs, Tornell, and Velasco regression to the same variables during the 1997 Asian crisis. Similar to the results of Furman and Stiglitz, they find that the regression fits relatively poorly for the

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<sup>9</sup> These ranges are based on the studies surveyed in Begg (1999), Bussière and Mulder (1999) and Nitithanprapas (2000).

<sup>10</sup> One of the reasons for the variety of findings on the effects of real appreciation are the substantial differences in the calculations used in different studies. See Begg (1999).

1997 samples and that only the lending boom combined with low reserves and weak fundamentals is significant and of the correct sign. They find that the real exchange rate appreciation has no impact on severity of the 1997 Asian crisis.

Tornell (1999) applies the Sachs, Tornell and Velasco model for the 1994 Mexican crisis, for the 1997 Asian crisis, and for the combination of the two crises, with a different sample of 23 countries.<sup>11</sup> He finds that the Sachs, Tornell and Velasco model fits fairly well for the Tequila crisis, the Asian crisis, and the combined crises.<sup>12</sup> Particularly, the cross-country variation in the crisis severity was largely determined by the three fundamentals: real exchange rate appreciation, lending booms, and low international reserves. Tornell interprets the good fits of his regressions to mean that “the rule that links fundamentals to the crises’ severity has been the same in both the Tequila and Asian crises” (p.1).

In summary, the Sachs, Tornell, and Velasco model clearly makes a major contribution in showing the important role that adequate levels of international reserves can play in protecting countries from currency crisis and that proxies for fragility of the domestic banking system are an important part of the fundamentals. The further empirical applications of their model raise questions, however, about its capability to explain the Asian crisis and about the usefulness of including measures of real exchange rate appreciation and current account deficit among the fundamentals. In the following

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<sup>11</sup> The samples include Argentina, Brazil, Chile, Colombia, Hong Kong, Hungary, India, Indonesia, Korea, Jordan, Malaysia, Mexico, Pakistan, Peru, Philippines, Poland, South Africa, Sri Lanka, Taiwan, Thailand, Turkey, Venezuela, and Zimbabwe.

<sup>12</sup> Commenting on an early version of Tornell’s paper, Berg and Pattillo (1999a) argue that Tornell’s good results are due to a variety of apparently small modifications and suggest that this shows the fragility of this approach.



section we discuss problems in creating proxies for the strength of currency crisis and develop a composite variable approach that focuses on the interrelationships among real exchange rate appreciation, current account deficits, and foreign direct investment. We use this model both to study the patterns of contagion and to test several hypotheses such as the Lawson dogma and the joint importance of exchange rate and current account development.

## **Methodology**

### Dependent Variable: A Crisis Index

In order to determine the degree of vulnerability to financial contagion or the severity of crisis, an operational definition of crisis is needed. A currency crisis is defined as speculative pressures in the foreign exchange markets. Following Eichengreen, Rose, and Wyplosz (1994) (1995), the speculative pressures can be reflected in a change in nominal exchange rate (devaluation/depreciation), a change in international reserves, or a change in interest rates.<sup>13</sup> The basic idea is that when there are speculative runs on currency, the government has three policy choices. First, it can let the exchange rate depreciate. Second, it can intervene in the foreign exchange markets by selling international reserves. Lastly, it can increase interest rates to entice capital inflows in order to offset the speculative pressures on domestic currency. Some countries may use a combination of these three policy options to absorb speculative pressures.

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<sup>13</sup> This concept is essentially in the exchange market pressure variable advanced by Girton and Roper (1977).

Because there is no cross-country comparable interest rate data for emerging countries, we exclude the change in interest rate from the crisis index as have other studies. Thus, the crisis index is a weighted average of the depreciation rate of the nominal exchange rates and the percentage change in international reserves. An increase in the crisis index, caused by an increase in the depreciation/devaluation rate or a drop in foreign exchange reserves corresponds to a more severe crisis. Note that this type of crisis index is a continuous variable that can measure the degree of crisis intensity.<sup>14</sup>

The difficult with this concept is how to weight the importance of changes in reserves versus changes in exchange rates. As Eichengreen et al.(1994) (1995) argue that ideally the weights should be derived from the excess demand for foreign exchange from an empirical model of the exchange rate, i.e. by the slope coefficient that reflects how much official intervention (change in reserves) would be required to avoid a one percentage point change in the exchange rate. The problem is that, as they note, there is little agreement within the profession about the most appropriate theoretical model of the foreign exchange market and none of our models fit well empirically. Thus they note that it is important to check the sensitivity of the results to the weights used. Unfortunately, however, most of the subsequent literature has paid no attention to this important warning.<sup>15</sup> Instead most studies have followed Eichengreen et al.'s suggestion to use calculations of precision, the inverse of the variance, of the variables as weights without either reporting these weights or checking the sensitivity of the results to different weights.

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<sup>14</sup> Some papers use discrete measures of crisis, typically when the index value deviates from its mean by more than two or three standard deviations.

<sup>15</sup> An exception is Glick and Hutchison (1999).

The only instances of which we are aware that the weights are reported are in Weber's (1995) discussion of Eichengreen et al's (1995) original paper. There the weights were 7.5 for changes in the exchange rate and 51.9 for changes in interest rates where changes in reserves are given a unit weight. Weber questioned these weights and suggested an equal weighting instead.

Not surprisingly precision weights can vary drastically across countries and time as devaluations occur and exchange rate regimes are changed. For example in our sample using two years of monthly data to calculate the precision weights, given to reserve changes when exchange rate changes are given a unit weight for the Mexican crisis they range from 17.87 for Brazil to 0.00 for Indonesia, Pakistan, Argentina and Jordan. From the Asian crisis the weight for Brazil dropped to 0.00 where it was joined by Argentina, China, and Uruguay. Venezuela took over the highest weight with 7.29, up from 1.75 for the Mexican crisis.

What was much more surprising to us was that large changes in the weights typically had relatively little effect on the ordinal rankings of countries in terms of the severity of speculative pressure. This explains why our empirical results show little sensitivity to changes in the weights. (We varied the weights from 10.00 to 0.1). As will be discussed later, what does appear to affect the results of different studies substantially is the large differences in calculation of real exchange appreciation.

This is particularly unfortunate because precision weights are inappropriate for use in the calculation of indices of currency crisis. They would be entirely appropriate for the calculation of indices of volatility or crisis based on averages of free market variables such as stock market indices for a number of different countries. The idea is to

capture the degree of volatility in a particular market at a particular time in relation to its normal volatility. If, for example, one variable is normally much more volatile than another, then an unweighted average would be excessively heavily driven by the behavior of the more volatile series. Many foreign exchange markets, however, are managed by governments. The relative variance of exchange rate changes and reserve changes will be heavily influenced by the exchange rate regime being followed and precision measures will reflect the government's reaction function, not the slope of the excess demand schedule in the foreign exchange market.

As a consequence, precision weights will substantially understate the severity of unsuccessful speculative attacks under fixed exchange rates such as hit Argentina following both the Mexican and Thai crisis and hit Hong Kong during the Asian crisis. This is easy to see. Under a regime of narrow band fixed exchange rates, almost all of the effects of incipient payments imbalances will fall on changes in reserves rather than changes in exchange rates. Since reserve changes will have a much higher variance, precision weights will give reserve changes little weight. Thus as long as the speculative attacks are unsuccessful their magnitude will be understated. By the same token, if a country is successfully knocked off from a narrow band peg, the heavy weight given to the subsequent currency depreciation will overstate the magnitude of speculative pressure.

One approach to guesstimating the weights would be to assume a foreign exchange market with rational expectations and calculate how much of a change in the exchange rate would be required to bring about an adjustment in the current amount equal to the size of the intervention. This would correspond to a flow equilibrium on the

assumption that the intervention would be repeated each period. In this case we could use the Marshall – Lerner conditions to derive the slope coefficient as a function of the sum of the country's demand elasticity for exports and imports. Since the crisis indices focus on the percentage change in reserves, the initial level of reserves also needs to be specified. Taking the ratio of reserves to imports is also a convenient formulation in relation to the Marshall – Lerner equation. See Nitithanprapas (2000).

Our high weight on reserves corresponds to such a long run flow equilibrium for a country with fairly high elasticities and/or ratio of reserves to imports. In addition to our base case of equal weighting we also report ratios of four to one and one to four to check the sensitivity of our results. During crisis, however, speculative considerations and risk aversion could lead to short-run slope coefficients that differed substantially from these long-run trade-based calculations. These considerations could cut in either direction. With strongly held expectations, speculative capital flows could add to the elasticity of the excess demand schedule, thus increasing the weight that should be given to changes in reserves. On the other hand, a substantial increase in uncertainty associated with a crisis could make the speculative and excess demand schedules much less elastic, increasing the weight that should be given to exchange rate changes in the crisis index. Our one to four ratio of weights corresponds to this latter view of foreign exchange markets during crisis. (For arguments that this was frequently the case during the Asian crisis see Willett (2000)). Thus there appears to be a substantial range of plausible weights for the crisis index. Fortunately, however, our sensitivity analysis presented in the last section finds that our major findings are robust with respect to substantial changes

in the weights in the crisis index.<sup>16</sup> We believe that it is important, however, to recognize that the precision of precision weights is largely spurious.

### **Independent Variables**

It has been hypothesized that crisis contagion across countries is systematically related to weak economic fundamentals. The crisis contagion is defined as when a crisis in one country increases the probability of a crisis in another country. However, the crisis contagion can be divided into two concepts: fundamentals-based contagion, where the spread of crisis can be explained by economic and political fundamentals, and true contagion, where the spread of crisis is caused by herding behavior fundamentals. In this paper, we focus on fundamentals-based contagion and search for common fundamental factors that may be able to explain at least some of the crisis contagion. The fundamental factors are divided into three groups: external vulnerability, internal vulnerability, and vulnerability to capital flight. The factors used here as independent variables are explained below.

#### **- External Vulnerability**

International currency crises should be due primarily to actual or incipient balance of payments disequilibrium. The balance of payments problem results from interrelations among variables that fail to provide equilibrium. Equilibrium, in economic analysis, is “a constellation of selected interrelated variables so adjusted to one another that no inherent tendency to change prevails in the model which they constitute” (Machlup, 1964, p.119).

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<sup>16</sup> While we report only the results for the one to one, four to one, and one to four ratios, as we think these are a plausible range, we also checked ratios running from ten to one to one to ten and found that even variations this large did not have major effects on the results.

In the Sachs et al. model, it is implicitly assumed that real exchange rate variable is the summary variable for balance of payments problems. However, balance of payments disequilibrium may not result from real exchange rate appreciation alone, nor will the extent of real appreciation necessarily be the best indicator to use. Although there are many variables that may indicate and/or contribute to balance of payments problems, this paper focuses on interrelations among several important ones; the budget balance, current account, real exchange rate, and capital flows.<sup>17</sup> In this paper, several composite variables are designed to test whether or not the interrelations among these variables increase the severity of crisis.

#### 1) Fiscal Budget and Current Account

The “Lawson Dogma” suggests that the current account deficit is worrisome only if it is caused by a high fiscal deficit.<sup>18</sup> According to the national income identity, the current account is equal to the sum of the budget deficit and the gap between private investment and private saving. The “Lawson Dogma” claims that the imbalance in the private investment-saving decisions reflects an intertemporal adjustment to smooth consumption, thus need not to be worried. The basic idea of this view is that a fall in net private saving (or an increase in current consumption) occurs when consumers expect higher future income and higher permanent income. However, many economists argue that “the Lawson Dogma” does not hold because private rather than public deficits

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<sup>17</sup> IMF (1999b) studies have also considered composite indicators of vulnerability to contagion between crisis and noncrisis countries, but have not reported econometric tests for the significance of the composite indicators.

<sup>18</sup> For discussions of the influence of the Lawson dogma on analysis of Mexico prior to its crisis, see Dornbusch et al. (1995) and Willett (2000).

largely caused the crisis in Mexico in 1994, and in a number of Asian countries in 1997-1998. It is, thus, interesting to test whether or not such claims hold.

## 2) Real Exchange Rate and Current Account

A current account deficit should be more worrisome if it is accompanied by a real exchange rate appreciation. The basic idea is that a real exchange rate appreciation due to capital inflows under a flexible exchange rate or domestic inflation above foreign levels under a pegged rate will cause a loss of competitiveness, thus worsening the current account deficit. Hence, the more appreciated the real exchange rate is, the higher the rate of depreciation or devaluation that is needed to generate a more sustainable current account position.

On the other hand, if real appreciation is due primarily to higher rates of productivity growth, then this should not be a source of declining competitiveness and future balance of payments problems. Thus it is when real appreciation and large current account deficits are found together that the situation should be most worrisome. The current account deficit can thus help to screen the “bad” real exchange rate appreciation from the “good” real exchange rate appreciation. The “good” real exchange rate appreciation, resulting from an increase in productivity in the tradable sectors relative to the nontradable sectors, generates a current account surplus and need not be cause of worry. On the other hand, when the real exchange rate appreciation is accompanied by a



current account deficit, it may signal a “bad” appreciation that would reduce the competitiveness and worsen the current account deficit.<sup>19</sup>

This approach can be implemented through a dummy variable threshold analysis either by including the current account deficit when real appreciation is above a threshold or by including the amount of real appreciation when the current account deficit is above a threshold. One way does not seem clearly preferable to the other on theoretical grounds so we test both.

Note that this relationship is of particular interest because real exchange rate and current account variables are the most controversial indicators in terms of empirical results across studies. Dominick Salvatore (1999) excludes the real exchange rate variable from his preferred indicators because he argues it does not add information to that contained in the current account variable. On the other hand, Kaminsky et al. (1998) exclude the current account from their preferred set of warning indicators of currency crisis on the basis of its poor performance in earlier studies. They suggest that it does not add information to that embodied in the real exchange rate variable. These opposite views clearly highlight the need to pay more attention to potential interaction between the current account and the real exchange rate.

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<sup>19</sup> The importance of this point has not escaped the IMF. The May 1999 World Economic Outlook notes that “a variable that may not be significant in isolation may be important because of its interaction with others; conversely, a variable that may appear relevant on its own may no longer be so when other variables are considered” (p. 79) and gives the example of real exchange rate appreciation due to productivity growth. They group variables into composite indicators of external imbalances, internal imbalances, trade spillovers, and financial vulnerability. For external balances they use a weighted average of measures of real appreciation, productivity growth in the export sector and current account deficits, but do not consider the threshold approach. Comparing the indicators for crisis and non-crisis countries in a large sample of 20 industrial and 41 emerging market countries they conclude that “External imbalances were particularly important for differentiating between crisis and non-crisis countries for emerging markets and during the Asian and Russian crisis” p. 80.

### 3) Current Account Deficit, FDI, and Real Exchange Rate Appreciation

It is widely held that a current account deficit is less worrisome if it is financed by foreign direct investment. See, for example, Salvatore (1999), Bussière and Mulder (1999), Frankel and Rose (1996), and Chuhan et al. (1997,1996). Foreign direct investments are less susceptible to capital flight because investors cannot liquidate their fixed properties, such as plants and machines, in a short period of time when a shock occurs.<sup>20</sup> On the other hand, the portfolio investors or short-term lenders can sell their assets or refuse to rollover their loans relatively quickly. In this case, the country with a current account deficit must induce severe adjustments by devaluing the domestic currency or by reducing domestic absorption to close the gap, thus intensifying the crisis. Another explanation is that foreign direct investment is commonly used to finance investment that helps to generate future earnings, while short-term and portfolio capital flows can be used to finance consumption that would worsen the future current account deficit. Thus, foreign direct investment is likely to be associated with better prospects for future export growth.

Therefore, balance of payments problems should be less likely the higher the proportion of a current account deficit that is financed by FDI and when this is not accompanied by substantial real exchange rate appreciation that would cause additional worsening of the current account deficit.

#### - Domestic Vulnerability (Banking Problem)

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<sup>20</sup> Of course, multinational corporations are likely to also have liquid funds which can be moved so this distinction should not be overdrawn. See more discussion of this view in Dooley et al. (1994).

Unlike simple balance of payment crises, the Mexican crisis in 1994 and the recent Asian crisis in 1997 show that banking problems can be a major source of a country's vulnerability. In particular, when the banking system is weak, the government is reluctant to raise interest rates to defend the exchange rate because the higher rates might weaken the banking systems. As a consequence, the weaker the banking system, the more likely are speculators to attack the currency. The task of measuring bank weaknesses is a difficult one. Most recent empirical studies, including those reviewed in section 2, have used the growth rate of bank claims on the private sector as a proxy of bank weakness. The basic idea is that when lending expands very fast in a short period of time, it is very difficult for banks to separate good projects from bad and it is very difficult for authorities to supervise the banks, thus decreasing loan quality and increasing the vulnerability of banks.

#### - Vulnerability to Capital Flight

A country is more vulnerable to capital flight when the country's short-term obligations in foreign currency surpass the country's foreign reserves. In particular, in the onset of a crisis when investors lose confidence, they move assets out of the country. However, if the country has enough international reserves to offset all short-term capital outflows, the country remains liquid. In order to evaluate the adequacy of international reserves, they should be compared to short-term obligations that investors can move at short notice. Thus in contrast to the traditional use of the ratio of reserves to imports, Calvo (1996) suggests the scaling of international reserves by liquid monetary assets (M2) because investors can convert them quickly into foreign currency in the short-run. Radelet and Sachs (1998) and Furman and Stiglitz (1998) argue that the ratio of short-

term international debts to foreign reserves is a powerful measure of illiquidity because foreign creditors can refuse to roll over short-term loans in the short run. We consider both indicators.<sup>21</sup>

### **Data Set and Country Sample**

Most of our data set are from the IMF's International Financial Statistics CD-ROM. The exception are the real exchange rate variable and the external debt variable.. The real exchange rate used in this paper is the real effective exchange rate index from the J.P. Morgan real exchange rate database.<sup>22</sup> The external debt data are from the database of the joint institutes of OECD, BIS, World Bank , and IMF. The construction of variables is presented in the data appendix. Since an estimation of factors of vulnerability to recent financial crises in emerging economies is the main focus of this paper, the samples are selected from the *Comparative Statistics for Emerging Market Economies* of the Institute of International Finance (IIF), with the exclusion of the oil-exporting countries and some transitional economies in Eastern Europe because of poor or unavailable data. However, the sample includes the two developed countries, Singapore and Hong Kong, that were relevant in the recent Asian financial crisis. The complete list of countries is Argentina, Brazil, Chile, China, Colombia, Egypt, Hong Kong, Hungary, India, Indonesia, Jordan, Malaysia, Mexico, Morocco, Peru, Pakistan, Philippines, Singapore, Sri Lanka, South Africa, South Korea, Thailand, Turkey,

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<sup>21</sup> A problem of course is that a country net reserve positions may differ substantially from its officially report gross reserve position. For example, Thailand had net reserve position in May 1997 only 5.3 billion U.S. dollar, due to the sales of the forward contract of 28 billion U.S. dollar.

<sup>22</sup> See the construction of the J.P. Morgan real effective exchange rate in J.P.Morgan (1994).

Uruguay, Venezuela and Zimbabwe.<sup>23</sup> Since the sample size for both the 1994 Mexican crisis period and the 1997 East Asian crisis is small (26 data points each), this empirical study stacks data across countries from both the Mexican and Asian crisis periods, making a total of 52 observations. The basic motivation of pooling the samples is that it provides more efficient estimation and inference. Another major benefit of combining the two crisis episodes is that the model, if properly specified, can be used to test whether the factors that influenced the ripple from the “Asian Flu” are broadly similar to those of the 1995 “Tequila Effect”.

### **Estimation Method**

The slope dummies regression is chosen as the estimation method.<sup>24</sup> This specification allows the coefficient to be different depending on the condition specified by the dummy variable. Essentially, the slope dummy variables allow us to consider interactions among fundamental factors of vulnerability. The effects of external or internal problems on severity of the crisis index depend on whether a country has high or low international reserves. Hence, the estimated regression takes the form:

$$IND = b_1 + b_2 (COM_i) + b_3 (LB) + b_4 (COM_i * Dhr) + b_5 (LB * Dhr) + \varepsilon$$

IND = Indicator-weighted average of the exchange rate change with respect to the U.S. dollar and the percentage change in foreign reserves.

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<sup>23</sup> The samples have six more countries than Sachs et al. (1996), three more countries than Tornell (1999), but eight less countries than Furman and Stiglitz (1998).

<sup>24</sup> For an econometric analysis of the slope dummies regression, see Studenmund (1998).

COM<sub>i</sub> = Composite variables of balance of payments disequilibrium (i = the number of the composite variable), where COM 1 = (Current Account/GDP) if (Budget Deficit/GDP) > x Percent<sup>25</sup>, where x is initially taken as 3 percent,<sup>26</sup> and

= 0 Otherwise.

COM2 = Real Effective Exchange Rate if (Current Account/GDP) < y percent, where y is initially taken as -5 percent,<sup>27</sup> and

= 0 Otherwise.

COM3 = (Current Account/GDP) if Real Exchange Rate Appreciation > z percent, where z is initially taken as 10 percent,<sup>28</sup> and

= 0 Otherwise.

COM4 = (Current Account/GDP)– (FDI/GDP) if Real Exchange Rate Appreciation > w percent, and

= 0 Otherwise.

LB = Percentage change in the ratio of the claims on private sectors by banks to GDP over the preceding four-year period<sup>29</sup>

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<sup>25</sup> In all cases, the size of the threshold effects assumed are somewhat, but not entirely, arbitrary. The results of sensitivity testing for the levels of thresholds is discussed below.

<sup>26</sup> Salvatore (1999) argues, “although there is no specific level of the budget deficit that spells inevitable trouble, a budget deficit of 3 percent of GDP or larger can usually be taken as a serious warning signal of possible future problems for the nation”(p. 343).

<sup>27</sup> Summers (1995) suggests “that close attention should be paid to any current account deficit in excess of 5% of GDP” (p. 47).

<sup>28</sup> The optimal threshold of real exchange rate appreciation for both currency and banking crises has been estimated to be 10 percent (Goldstein, 1997).

<sup>29</sup> This period of lending booms is used so as to be able to compare with the previous studies. However, different time periods are used to test for the sensitivity analysis.

$D_{hr}$  = Dummy for high international reserves, where

$D_{hr} = 1$  if the ratio of M2 to the stock of foreign reserves is less than the lowest quartile of the sample<sup>30</sup>, and

$= 0$  Otherwise.

The multiplication of the  $COM_i$  and  $D_{hr}$ , and the  $LB$  and  $D_{hr}$  are the interaction terms. This means that when a country lacks high international reserves, the effect of a composite external imbalance and a lending boom would be captured by  $b_2$  and  $b_3$ . When a country has high international reserves, on the other hand, the effects of a composite external imbalance and a lending boom are captured by  $b_2 + b_4$  and  $b_3 + b_5$ . The hypotheses on the signs and the significant effects of coefficients are as follows. Firstly, a composite variable ( $COM_i$ ) matters when a country has a lack of high international reserves, i.e.,  $b_2 > \text{or} < 0$ , but does not matter when a country has high international reserves, i.e.,  $b_2 + b_4 = 0$ . Secondly, a lending boom ( $LB$ ) also only matters when a country lacks high international reserves, i.e.,  $b_3 > 0$ , but it does not matter when a country has high international reserves, i.e.,  $b_3 + b_5 = 0$ .

This estimation method is similar to the Sachs et al. formulation, except that this model does not have the interactive term between fundamental variables and the dummy for weak fundamentals, which is created by ranking the same fundamental factors in the quartile scale. By excluding the dummy for weak fundamentals, we are able to aggregate other important fundamental factors into the composite variable. The ideal estimation would be to consider all of the important factors and the dummy for weak fundamental

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<sup>30</sup> This definition is used so as to be able to compare with the previous studies. Different definitions are used in the sensitivity analysis.

factors simultaneously. Nonetheless, given the small sample size, this would cause problem from lack of degrees of freedom. Thus, to focus on interrelations among fundamental variables that are of particular interest, the estimation method considers only the interaction between the composite of fundamental indicators and the dummy for high international reserves. The estimated results are presented in the next section.

### **Empirical Results**

The “Lawson Dogma” argues that the current account deficit is worrisome only if it is caused by fiscal deficits. COM1 variable is used to capture the interrelation between the current account deficit and the fiscal budget deficit. The COM1 is current account over GDP if the government budget deficit over GDP is greater than the threshold of three percent; otherwise, it is zero. The regression results in table 1 show that the estimated coefficient of COM1 (b2) in countries lacking high foreign reserves are negative, although insignificant, in 1994 sample, in 1997 sample, and in the combined samples. The result implies that the “Lawson Dogma” fails to explain the 1994 and the 1997 crises and that the absence of a budget deficit does not guarantee that a country will not have a crisis, although a substantial deficit makes a crisis more likely. The coefficients of lending booms (b3) in countries lacking high reserves are positive and significant in all samples. This means that excessive credit expansion, as a proxy of bank weaknesses, increases the vulnerability of a country to a crisis. The Wald coefficient test cannot reject the null hypotheses of  $b2 + b4 = 0$  and  $b3 + b5 = 0$ , implying that high international reserves can prevent vulnerable countries from suffering a severe crisis. The adjusted R-squareds for the 1994 sample, for the 1997 sample, and for the combined samples are 0.42, 0.05, and 0.29, respectively.



## ADD TABLE 1

Table 2 shows the regression results using the first combination (COM2) of real exchange rate appreciation and current account deficits. For the 1994 Mexican crisis period, shown in column 3, the estimated coefficient of COM2 (b2) is, as expected, positive and significant at the 5 percent level in the absence of high foreign reserve countries. This implies that a “bad” real exchange rate appreciation, screened by the current account deficit, increases the severity of the crisis. The estimated coefficient of the lending booms (b3) is also positive and significant in the absence of high foreign reserve countries. The Wald coefficient tests indicate that the hypotheses of  $b2 + b4 = 0$  and  $b3 + b5 = 0$  cannot be rejected, implying that high foreign reserves can protect an otherwise vulnerable country from suffering a severe crisis. Similar results are obtained when applying the COM2 to the 1997 East Asian Crisis (see column 4) and to both the 1994 Mexican crisis and the 1997 crisis together (see column 5). Although considering a real exchange rate appreciation by itself may not be significant<sup>31</sup>, it has a significant effect on the severity of crises when considered in interrelation to the current account deficit.

The adjusted R-squareds for our equations rise in all samples compared with the COM1 formulation. They are also higher than in the Sachs, Tornell and Velasco model in which real exchange rate appreciation is put into the regression independently. The 0.55 adjusted R-squared in the Mexican crisis sample is a little higher than the 0.54 adjusted R-squared of the model in Sachs et al. (1996). In the Asian crisis sample, the

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<sup>31</sup> As was found in Furman and Stiglitz (1998), our real exchange rate variable is insignificant when we entered it independently in the regression.

0.21 adjusted R-squared is much higher than the  $-0.16$  of the regression in Furman and Stiglitz (1998). This suggests that the model has considerable explanatory power with respect to the severity of Asian crisis in 1997. In the combined crises, the 0.39 adjusted R-squared is roughly the same as that of the regression in Tornell (1999).

#### ADD TABLE 2

Table 3 shows the regression results using the alternative combination (COM3) of current account deficit and real exchange rate appreciation. COM3 is a current account balance over GDP if the real effective exchange rate appreciates by more than the ten-percent threshold; otherwise, it is zero. We know of no theoretical reason to prefer one formulation over the other. Thus, we tried both. As expected, the coefficients of COM3 (b2) in the absence of high reserve countries are negative and significant at 5 percent in all three samples. They vary much less across periods than do those with the COM2 formulation. The point estimates of coefficients b2 are  $-4.91$ ,  $-4.99$ , and  $-4.96$  for the 1994 Mexican crisis sample, the 1997 East Asian crisis sample, and for combined samples, respectively. These results suggest that a current account deficit that is caused by a real exchange rate appreciation plays a significant role in increasing a country's vulnerability to contagion. In addition, the coefficients of lending booms (b3) in the absence of high reserves are positive and significant at 5 percent in all three cases. The point estimates of b3 for the 1994 Mexican crisis, the 1997 East Asian crisis, and both episodes are more stable than in the COM1 and COM2 formulations, being 0.23, 0.22, 0.22, respectively. These fall roughly in the middle of the range of estimates found in Tables 1 and 2 (0.14 to 0.30). These results suggest that bank weakness also plays an important role in determining the severity of currency crisis. The Wald coefficient tests

cannot reject the null hypotheses of  $b_2 + b_4 = 0$  and  $b_3 + b_5 = 0$ , implying that both the effect of COM3 and the effect of Lending Booms matter only in countries that lack high international reserves.

Compared to the adjusted R-squareds of the COM2 regressions, the adjusted R-squared of the COM3 regressions are higher in all samples. The adjusted R-Squared for the 1994 sample is 0.64 as compared with 0.55 for the COM2 model over the same period. The adjusted R-squared is 0.28 for the 1997 sample compared with the 0.21 for the COM2 model over the same time period. In the combined 1994 and 1997 sample, the adjusted R-squared is 0.52 for COM3 compared with 0.39 for the COM2 model.

These results question the interpretations of Sachs et al. (1996) and Kaminsky and Reinhart (1996) that their insignificant results for the current account deficit when it is entered independently suggests that the current account deficit plays no role in explaining the pattern of currency crisis. In our analysis the current account deficit is in fact very significant when it is combined with substantial real exchange rate appreciation

Given the better fit of the COM3 than the COM2 formulation of the interrelationship of appreciation and the current account deficit, we use it when we replace the current account deficit with the portion of the deficit not financed by FDI.

### ADD TABLE 3

COM4 is the current account over GDP, minus FDI over GDP, if the real exchange rate appreciates by more than the ten-percent threshold<sup>32</sup>; otherwise, it is zero.

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<sup>32</sup> Different definitions of variables and a variety of thresholds are used to test the robustness of the results in the next section.

Table 4 shows that the estimated coefficients of COM4 (b2) are negative and significant at the 5 percent level in all samples. The point estimates of b2 are -3.75 for the 1994 Mexican crisis, -4.24 for the 1997 East Asian crisis, and -3.93 for the combined crises. The Wald coefficient test can not reject the null hypothesis  $b2 + b4 = 0$ , supporting the hypothesis that the effect of COM4 on the severity of the crisis index matters only in countries lacking high international reserves. In other words, again we find that high international reserves can prevent countries with external deficits from suffering a severe crisis. The estimated coefficients of lending booms (b3) are positive and significant at the five-percent level in all samples. The point estimates of b3 are 0.25 for the 1994 Mexican crisis, 0.20 for the 1997 East Asian crisis, and 0.22 for the combined episodes. The null hypothesis of  $b3 + b5 = 0$  cannot be rejected by the Wald coefficient test, implying that high international reserves can prevent countries with internal problems from suffering a severe crisis.

The R-squareds and adjusted R-squareds for all regressions fit all samples quite well. In order to evaluate the fits of the results, the adjusted R-Squared is compared to the best-fit regression from the previous model using the COM3. The adjusted R-square of 0.67 for the 1994 sample is higher than the 0.64 for the model using the COM3 over the same sample. The adjusted R-squared of 0.22 for the 1997 sample, however, is a little smaller than the 0.28 for the model using the COM3 variable over the same time period. The adjusted R-squared of 0.52 is similar to that of the model using the COM3 variable for the combined sample. Thus there is not a clear basis in the statistical results for choosing between these two formulations. On theoretical grounds we prefer COM4 and thus take it as our base case for the sensitivity testing reported below.

ADD TABLE 4

ADD TABLE 5

### **Structural Stability Test**

Because the sample size during the 1994 Mexican crisis period and during the 1997 East Asian crisis is so small (26 data points each), we choose the regression that pools observations for the 1994 and 1997 crises as the benchmark, to give a higher confidence in the estimation results, which is represented in the last column of table 4. In order to use this benchmark with confidence, however, the Chow Structural Stability test is used to see whether the 1994 crisis and the 1997 crisis are identical in structure. We find that the observed F-value from the Chow test is 0.47, with a p-value of 0.79, which is lower than the critical value at the 5-percent significance level. Thus, the null hypothesis of identical structures cannot be rejected. This result presents a counter to the allegations that economists have to come up with a new theory after each financial crisis.

### **Sensitivity Analyses**

Since the benchmark regression takes into account the cross-sectional and time-series characteristics of the two crisis episodes and implicitly assumes that the regression parameters do not differ between various countries. We tested for fixed and random effects in table 5 and found that the null hypothesis of no fixed effects and no-random effects cannot be rejected.<sup>33</sup>

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<sup>33</sup> Bussière and Mulder (1999) and Tornell (1999) find similar results.

To test the sensitivity of the benchmark results, we perform a number of tests. We test whether the benchmark regression is sensitive to different crisis index intervals and to different weights on reserve and exchange rate changes in the crisis index. Different definitions of the current account deficit, foreign direct investment, and lending booms are considered. We also test whether the benchmark regression is sensitive to different thresholds for the real exchange rate appreciation, and to different definitions of the international reserve adequacy dummy.

#### - Sensitivity Analysis of the Results to Different Crisis Index Intervals

We vary the time period crisis index from the month preceding the onset of the Mexican crisis (November 1994) and the East Asian crisis (June 1997) to six months later. Recall that following Sachs et al. the benchmark regression uses the crisis index for the period of four months, i.e., from November 1994 to March 1995 for the Mexican crisis, and from June 1997 to October 1997. Table 6 shows that the signs and the significance of all coefficients are the same across the six periods. The estimated coefficients of COM4 (b2) are significant and negative for all crisis intervals. Similarly, the coefficients of lending booms (b3) are significant and positive for all crisis intervals. When the length of the crisis interval is longer, the fundamental factors appear to play a larger role in determining the pattern of contagion across countries. In all crisis intervals, the null hypotheses of  $b2 + b4 = 0$  and  $b3 + b5 = 0$  cannot be rejected. However, the R-squareds and adjusted R-squareds decline as the time period is extended.

#### ADD TABLE 6

#### - Sensitivity Analysis of the Results to Different Weights in the Crisis Index

In order to investigate whether the weights of each component of the crisis index have a substantial impact on the estimated results, two alternative weights –one that gives more weight to a change in exchange rate and one that gives more weight to a change in foreign reserves – are used. Column 3 in table 7 shows the results of the composite model whose crisis index assigns a 0.8 to a change in foreign reserves and a 0.2 to a change in the nominal exchange rate and column 4 shows the results of the benchmark model where the crisis index assigns a 0.2 weight to a change in foreign reserves and 0.8 weight to a change in the nominal exchange rate. Compared to the results of the benchmark model, whose crisis index is weighted equally, the signs, size and significance of the estimated coefficients are similar.  $b_2$  rises somewhat when more weight is given to reserve changes and falls when more weight is given to exchange rate changes. The coefficients on  $b_3$  are virtually unchanged. The hypotheses of  $b_2+b_4 = 0$  and  $b_3+b_5 = 0$  cannot be rejected. While the differences in the adjusted R-squareds are not great, the equal weighted version performs best on this score. In brief, the results are not sensitive to the weight of the crisis index.

#### ADD TABLE 7

- Sensitivity Analysis of the Results to Different Periods of the Current Account, FDI, and Lending Booms

Next, we test the sensitivity of the benchmark to different calculations of current account deficit, FDI, and lending booms. Note that the benchmark regression uses a five-year average of the current account over GDP and the FDI over GDP, and a five-year growth rate in lending booms. These definitions are chosen for the sake of comparison to

studies by Sachs et al. (1996), Furman and Stiglitz (1998), and Tornell (1999). Table 8 presents the sensitivity analysis for different length periods. Column 4 uses a four-year period prior to the crises in constructing the current account deficit, the foreign direct investment, and the growth rate in lending booms. Column 5 uses a three-year period and column 6 uses a two-year period. The signs and the significance of all coefficients are similar to those of the benchmark regression.

It should be noted that the magnitude of the COM4 coefficient (b2) decreases as the number of periods is shortened. This result is not surprising since the shorter the external problems persist, the less serious the problem appears. For example, one year of a current account deficit may reflect an intertemporal adjustment of people to smooth consumption and may be temporary because the current account deficit resulting from higher consumption today can be financed by the future surplus resulting from lower consumption tomorrow.

On the other hand, the magnitude of the coefficient on lending booms (b3) increases as the number of periods is shortened. Note also, however, that the adjusted R-squared of the equation grows consistently as the time interval is extended. While the coefficient on lending booms drops substantially, its standard error drops even more. Thus we conclude that the true coefficient is much more likely to lie in the 0.2 to 0.3 range estimated with the three to five year intervals than around the 0.6 level estimated from a two year interval.

ADD TABLE 8



- Sensitivity Analysis of the Results to Different Thresholds of Real Exchange Rate Appreciation

Next we tested whether the results from the benchmark regression are sensitive to the thresholds for the real exchange rate appreciation. In the benchmark regression, the COM4 variable is defined as the size of the current account deficit not financed by flows of foreign direct investment if the real exchange rate is greater than a 10-percent threshold. For sensitivity analysis, 15-percent, 7-percent, 5-percent, and 3-percent thresholds of real exchange rate appreciation are used to calculate the COM4 variable and put into the regression. The estimated results are presented in column 3, 4, 5, 6, and 7 of table 9. The estimated coefficients of the COM4 (b2) are negative and significant in all regressions. Interestingly, the magnitude of coefficient b2 increases as the threshold of real exchange rate appreciation increases. The result implies that the current account deficit is more worrisome if the real exchange rate is more appreciated. However, the standard errors of the coefficient of the COM4 variable increase as the threshold increases as well, and this reduces the significance of the estimated coefficient. The fits of all regressions are roughly the same, except for the 15 percent threshold where the adjusted R-squared falls to only 32 percent. The regression using a 3-percent threshold has the highest adjusted R-squared. These results suggest that there is not a clear threshold level for real exchange rate appreciation to be important.

ADD TABLE 9

- Sensitivity Analysis of the Results to Different Definitions of the High-Reserves Dummy

In the benchmark regression, the dummy for high reserves is one if the ratio of M2 to reserves is in the lowest quartile of the sample; otherwise it is zero.<sup>34</sup> By this definition, only one-fourth of the sample is classified as high-reserve countries. To test the sensitivity of the result, different quartiles of the sample are used to define the dummy variable. Column 4 in the table 10 defines the dummy of high reserves as when the ratio of M2 to reserves is below the second quartile of the sample. By this definition, half of the sample is classified as high-reserve countries, and the other half as non high-reserve countries. The estimated coefficients of the COM4 (b2) and lending booms (b3) variables change very little and the adjusted R-squared is almost identical. The Wald coefficient test cannot reject the null hypotheses of  $b2 + b4 = 0$ , and  $b3 + b5 = 0$ , suggesting that reserves in the top half of the sample can prevent vulnerable countries from suffering a severe crisis.

The fifth column in table 9 defines the dummy of high reserves as when the ratio of M2 to foreign reserves is below the third quartile of the sample. By this definition, 75 percent of the country sample is classified as high-reserve countries, and 25 percent of the samples is classified a non-high-reserve countries. The last column shows that the results deteriorate. The estimated coefficients of b2 and b3 are, of correct signs, but insignificant and the adjusted R-squared falls substantially. The Wald coefficient test of  $b2 + b4 = 0$  is rejected at the five-percent significance level. This suggests that countries must do more than just avoiding very low levels of reserves, but that super high levels of reserves do not offer substantially greater protection than high levels.

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<sup>34</sup> Given that there is no theoretical explanation about the high reserves in relation to M2, ranking the number by using a quartile scale is the way that most studies used to measure the high reserves. However, it may be better to find the optimal absolute level of high reserves. This subject is left for future research.

## ADD TABLE 10

The ratio of short-term foreign debt to foreign reserves is another suggested measure for reserve adequacy. The dummy for high short-term debts to foreign reserves takes the value of one if the ratio of short-term debts to foreign reserves is less than one; otherwise, it is zero. The threshold of one is set because there is theoretical explanation. “A ratio greater than one...does indicate vulnerability to a crisis: once something sparks a withdrawal of foreign capital, each foreign creditor has an incentive to demand repayment quickly, since each one knows that there is not enough foreign exchange to repay them all” (Radelet and Sachs, 1998, p. 25). The last column of table 9 presents the results of the regression using the dummy of short-term debts to foreign reserves to interact with the COM4 and the Lending Booms variables. The estimated coefficient of COM4 (b2) rises a good bit while the coefficient of Lending Booms (b3), remains almost the same as does the adjusted R-squared. The Wald coefficient test cannot reject the null hypotheses of  $b_2+b_4 = 0$  and  $b_3+b_5 = 0$ , implying that a low ratio of short-term debts to foreign reserves can reduce the severity of crisis. In short, there is not a substantial difference in results between the two different measure of foreign reserve adequacy in our model.<sup>35</sup>

## Conclusion

The econometric findings in this study suggest that fundamentals played a substantial role in explaining the contagion effects during the 1994 Mexican crisis and the 1997 Asian crisis. However, while the stability tests of the model cannot reject an

identical structure for the Mexican crisis and the Asian crisis periods, the model explains the pattern of “Tequila” effects much better than that of the “Asian flu.” The fundamentals from the best model explain 67 percent of the pattern of the Mexican crisis, but only 22 percent for the Asian crisis.

It should be noted that the regression is a parsimonious model that considers only a limited number of related fundamental variables. The regression results clearly understate the role of fundamentals in causing the contagion because there are other economic and political fundamentals that are not captured by the model. It can be concluded with confidence that the spillover effects after both the Tequila and Asian crisis were not entirely random as implied by a complete pure contagion view, but this does not rule out the possibility that pure contagion played some role.

The regression results are more definitive in terms of evaluating hypotheses about the sources of a country’s vulnerability to contagion. The lending boom, as a proxy of bank weaknesses and excessive credit expansion, is very significant and stable in all regressions, implying that the bank weaknesses and the domestic credit expansion increase a country vulnerability to a crisis. When considered independently in the regressions, the real exchange rate, the current account deficit and FDI, are significant only in some studies. When the three variables are combined together, however, they are significant in all of our regressions. Accordingly, we believe that the composite indicator of current account, FDI, and real exchange rate is a useful indicator of external vulnerability to financial contagion. Lastly, the estimation results suggest that adequate

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<sup>35</sup> Bussière and Mulder (1999) find that the short-term debt to reserves ratio works better than the M2 to reserves ratio in their analysis.

foreign reserves in relation to liquid money or in relation to short-term external debts can help prevent an otherwise vulnerable country from suffering a crisis. Thus reserve management should be given a prominent place in countries' strategies for dealing with potential currency crisis.<sup>36</sup>

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<sup>36</sup> See also Bussière and Mulder (1999), Fischer (1999) and Willett and Denzau (1999).

Table 1: Regression Results Explaining the Severity of Crisis Using the Com1 Variable<sup>a</sup>

Estimated Coefficient	Independent Variable	1994 Mexican Crisis	1997 East Asian Crisis	1994 and 1997 Crises
b1	Constant	-5.15 (3.11)	-0.82 (3.71)	-3.09 (2.32)
b2	COM1 <sup>b</sup> with an absence of high reserves	-0.86 (1.67)	-2.47 (2.26)	-1.51 (1.33)
b3	Lending booms with an absence of high reserves	0.30* (0.06)	0.18* (0.09)	0.26* (0.05)
b2+b4	COM1 with high reserves	-0.56	0.66	0.13
b3+b5	Lending booms with high reserves	0.01	0.02	0.01
Summary Statistic				
	R-Squared	0.52	0.20	0.35
	Adjusted R-Squared	0.42	0.05	0.29
Addendum: Wald Test				
	Ho: b2 + b4 = 0	p-value 0.83	p-value 0.74	p-value 0.80
	Ho: b3 + b5 = 0	p-value 0.67	p-value 0.82	p-value 0.66

Note: Standard errors are shown in parenthesis. One asterisk (\*) indicates statistical significant at a 5 percent level. Two asterisks (\*\*) indicate statistical significant a 10 percent level.

- a. The dependent variable is the crisis index from November 1994 to March 1995 for the Mexican crisis period, and from June 1997 to October 1997 for the Asian crisis period.
- b. COM1 is an average of current account deficit to GDP between 1990 and 1994 for the Mexican crisis and between 1992 and 1996 for the Asian crisis if the average of budget deficit to GDP for the same period is greater than 3 percent; otherwise, it is set to zero.

Table 2: Regression Results Explaining the Severity of Crisis Using the Com2 Variable<sup>a</sup>

Estimated Coefficient	Independent Variables	1994 Mexican Crisis	1997 East Asian Crisis	1994 and 1997 Crises
b1	Constant	-4.43 (2.83)	0.27 (3.17)	-1.55 (2.12)
b2	COM2 <sup>b</sup> with an absence of high reserves	0.89* (0.38)	3.80* (1.59)	1.13* (0.39)
b3	Lending booms with an absence of high reserves	0.30* (0.05)	0.14** (0.08)	0.24* (0.05)
b2+b4	COM2 with high reserves	1.721	-0.17	0.47
b3+b5	Lending booms with high reserves	0.02	0.02	0.01
Summary Statistic				
	R-Squared	0.63	0.35	0.44
	Adjusted R-Squared	0.55	0.21	0.39
Addendum: Wald Test				
	Ho: b2 + b4 = 0	p-value 0.36	p-value 0.95	p-value 0.66
	Ho: b3 + b5 = 0	p-value 0.50	p-value 0.89	p-value 0.71

Note: Standard errors are shown in parenthesis. One asterisk (\*) indicates statistical significant at a 5 percent level. Two asterisks (\*\*) indicate statistical significant a 10 percent level.

- a. The dependent variable is the crisis index from November 1994 to March 1995 for the Mexican crisis period, and from June 1997 to October 1997 for the Asian crisis period.
- b. COM2 is the real effective exchange rate appreciation from 1990 to 1994 for the Mexican crisis and from 1992 to 1996 for the Asian crisis if the average share of the current account deficit of the same periods is greater than 5 percent; otherwise, COM1 is set to zero.

Table 3: Regression Results Explaining the Severity of Crisis Using the Com3 Variable<sup>a</sup>

Estimated Coefficient	Independent Variables	1994 Mexican Crisis	1997 East Asian Crisis	1994 and 1997 Crises
b1	constant	-4.03 (2.49)	-0.004 (2.91)	-2.06 (1.81)
b2	COM3 <sup>b</sup> with an absence of high reserves	-4.91* (1.38)	-4.99* (1.76)	-4.96* (1.02)
b3	Lending booms with an absence of high reserves	0.23* (0.06)	0.22* (0.08)	0.22* (0.04)
b2+b4	COM3 with high reserves	1.79	-1.57	-1.26
b3+b5	Lending booms with high reserves	0.01	0.01	0.01
Summary Statistic				
	R-Squared	0.71	0.41	0.56
	Adjusted R-Squared	0.64	0.28	0.52
Addendum: Wald Test				
	Ho: b2 + b4 = 0	p-value 0.77	p-value 0.58	p-value 0.57
	Ho: b3 + b5 = 0	p-value 0.67	p-value 0.93	p-value 0.74

Note: Standard errors are shown in parenthesis. One asterisk (\*) indicates statistical significant at a 5 percent level. Two asterisks (\*\*) indicate statistical significant a 10 percent level.

- a. The dependent variable is the crisis index from November 1994 to March 1995 for the Mexican crisis period, and from June 1997 to October 1997 for the Asian crisis period.
- b. COM3 is the share of average current account deficit to GDP between 1990 and 1994 for the Mexican crisis and between 1992 and 1996 for the Asian crisis if the real effective exchange rate appreciates by more than 10 percent; otherwise, COM2 is set to zero.



Table 4: Regression Results Explaining the Severity of Crisis Using Com4 Variable<sup>a</sup>

Estimated Coefficient	Independent Variables	1994 Mexican Crisis	1997 East Asian Crisis	1994 and 1997 Crises ( <i>Benchmark</i> )
b1	Constant	-5.58 (2.44)	-0.43 (3.16)	-3.03 (1.90)
b2	COM4 <sup>b</sup> with an absence of high reserves	-3.75* (0.94)	-4.24* (1.71)	-3.93* (0.84)
b3	Lending booms with an absence of high reserves	0.25* (0.05)	0.20* (0.08)	0.22* (0.04)
b2+b4	COM4 with high reserves	0.005	-0.65	-0.69
b3+b5	Lending booms with high reserves	0.02	0.01	0.01
Summary Statistic				
	R-Squared	0.73	0.35	0.56
	Adjusted R-Squared	0.67	0.22	0.52
Addendum: Wald Test				
	Ho: b2 + b4 = 0	p-value 0.99	p-value 0.71	p-value 0.59
	Ho: b3 + b5 = 0	p-value 0.55	p-value 0.84	p-value 0.65

Note: Standard errors are shown in parenthesis. One asterisk (\*) indicates statistical significant at a 5 percent level. Two asterisks (\*\*) indicate statistical significant a 10 percent level.

- The dependent variable is the crisis index between November 1994 and March 1995 for the Mexican crisis, and between June 1997 and October 1995 for the Asian crisis.
- COM4 is an average, between 1990 to 1994 for the Mexican crisis and between 1992 to 1996 for the Asian crisis, of current account deficit to GDP less a share of foreign direct investment to GDP if a real effective exchange rate appreciation is greater than 10 percent threshold; otherwise it is zero.

Table 5: Fixed Effects and Random Effects of the Model Using the COM4 Variable<sup>a</sup>

Estimated Coefficient	Independent Variables	Fixed Effects	Random Effects	The Benchmark
b1	Constant		-3.07 (1.94)	-3.03 (1.90)
b2	COM4 <sup>b</sup> with an absence of high reserves	-4.05* (1.22)	-3.94* (0.84)	-3.93* (0.84)
b3	Lending booms with an absence of high reserves	0.24* (0.06)	0.23* (0.04)	0.22* (0.04)
b2+b4	COM4 with high reserves	-2.63	-0.74	-0.69
b3+b5	Lending booms with high reserves	0.001	0.01	0.01
Summary Statistic				
	R-Squared	0.79	0.58	0.56
	Adjusted R-Squared	0.51	0.55	0.52
Addendum: Wald Test				
	Ho: b2 + b4 = 0	p-value 0.43	p-value 0.58	p-value 0.59
	Ho: b3 + b5 = 0	p-value 0.99	p-value 0.66	p-value 0.65

Note: Standard errors are shown in parenthesis. One asterisk (\*) indicates statistical significant at a 5 percent level. Two asterisks (\*\*) indicate statistical significant a 10 percent level.

- The dependent variable is the crisis index between November 1994 and March 1995 for the Mexican crisis, and between June 1997 and October 1997 for the Asian crisis.
- COM4 is an average, between 1990 to 1994 for the Mexican crisis and between 1992 to 1996 for the Asian crisis, of current account deficit to GDP less a share of foreign direct investment to GDP if a real effective exchange rate appreciation is greater than 10 percent threshold; otherwise it is zero.

Table 6: Sensitivity Analysis of the Result to Different Crisis Index Intervals

	Independent Variables	Nov-Dec94 Jun-Jul97	Nov-Jan95 Jun-Aug97	Nov-Feb95 Jun-Sep97	Nov-Mar95 Jun-Oct97 <i>Benchmark</i>	Nov-Apr95 Jun-Nov97	Nov-May94 Jun-Dec97
b1	Constant	-1.58 (1.23)	-2.94 (1.57)	-2.69 (1.66)	-3.03 (1.90)	-0.87 (2.23)	0.34 (3.42)
b2	COM4 with an absence of high reserves	-2.25* (0.54)	-3.51* (0.73)	-3.35* (0.77)	-3.93* (0.84)	-4.03* (1.03)	-4.05* (1.58)
b3	Lending booms with an absence of high reserves	0.12* (0.03)	0.17* (0.04)	0.15* (0.04)	0.22* (0.04)	0.18* (0.05)	0.20* (0.08)
b2+ b4	COM4 with high reserves	-0.13	-0.58	-0.69	-0.69	-0.35	-0.24
B3+ b5	Lending boom with high reserves	0.001	0.008	0.009	0.01	0.005	-0.001
Summary Statistics							
	R-Squared	0.49	0.54	0.47	0.56	0.42	0.26
	Adj R-Squared	0.44	0.50	0.42	0.52	0.37	0.19
Addendum: Wald Tests							
	Ho: b2+b4 = 0	p-value 0.88	p-value 0.58	p-value 0.53	p-value 0.58	p-value 0.81	p-value 0.92
	Ho: b3+b5 = 0	p-value 0.93	p-value 0.71	p-value 0.64	p-value 0.66	p-value 0.87	p-value 0.97

Note: Standard errors are shown in parenthesis. One asterisk (\*) indicates statistical significant at a 5 percent level. Two asterisks (\*\*) indicate statistical significant a 10 percent level.

Table 7: Sensitivity Analyses of the Results to Different Weights of the Crisis index

Estimated Coefficient	Independent Variables	Assign more Weight to Foreign Reserve Change <sup>a</sup>	Assign more Weight to Exchange Rate Change <sup>b</sup>	Benchmark
b1	Constant	-6.59 (2.24)	0.52 (2.23)	-3.03 (1.90)
b2	COM4 with an absence of high reserves	-4.41* (0.98)	-3.45* (0.98)	-3.93* (0.84)
b3	Lending booms with an absence of high reserves	0.23* (0.05)	0.22* (0.05)	0.22* (0.04)
b2+b4	COM4 with high reserves	-0.68	-0.72	-0.69
b3+b5	Lending booms with high reserves	0.01	0.01	0.01
Summary Statistic				
	R-Squared	0.51	0.45	0.56
	Adjusted R-Squared	0.46	0.40	0.52
Addendum:Wald Test				
	Ho: b2 + b4 = 0	p-value 0.66	p-value 0.64	p-value 0.59
	Ho: b3 + b5 = 0	p-value 0.59	p-value 0.81	p-value 0.65

Note: Standard errors are shown in parenthesis. One asterisk (\*) indicates statistical significant at a 5 percent level. Two asterisks (\*\*) indicate statistical significant a 10 percent level.

a. The crisis index is defined as  $IND = 0.2(\% \Delta \text{Exchange Rate}) - 0.8(\% \Delta \text{Reserves})$ .

b. The crisis index is defined as  $IND = 0.8(\% \Delta \text{Exchange Rate}) - 0.2(\% \Delta \text{Reserves})$

Table 8: Sensitivity of the Result to Different Periods of the Current Account Deficit, the Foreign Direct Investment, and the Lending Booms

	Independent Variables	Five-Years Period <sup>a</sup> <i>Benchmark</i>	Four-Years Period <sup>b</sup>	Three-Years Period <sup>c</sup>	Two-Years Period <sup>d</sup>
b1	Constant	-3.03 (1.90)	-2.24 (2.02)	-1.40 (2.27)	0.21 (2.31)
b2	COM4 with an absence of high reserves	-3.93* (0.84)	-3.62* (0.81)	-3.03* (0.80)	-2.14* (0.74)
b3	Lending booms with an absence of high reserves	0.22* (0.04)	0.28* (0.06)	0.31* (0.09)	0.63* (0.19)
b2+b4	COM4 with high reserves	-0.69	-0.58	-0.43	-0.22
b3+b5	Lending booms with high reserves	0.01	0.01	0.01	-0.02
Summary Statistic					
	R-Squared	0.56	0.49	0.35	0.31
	Adjusted R-Squared	0.52	0.44	0.29	0.24
Addendum: Wald Test					
	Ho: b2 + b4 = 0	p-value 0.58	p-value 0.62	p-value 0.70	p-value 0.83
	Ho: b3 + b5 = 0	p-value 0.66	p-value 0.81	p-value 0.97	p-value 0.90

Note: Standard errors are shown in parenthesis. One asterisk (\*) indicates statistical significant at a 5 percent level. Two asterisks (\*\*) indicate statistical significant a 10 percent level.

- The benchmark regression uses the average of current account deficit and foreign direct investment to GDP between 1990 to 1994 for the Mexican crisis and between 1992 to 1996 for the Asian crisis. And lending boom is defined as the percentage change in the ratio of claims on private sectors to GDP from 1990 to 1994 for the Mexican crisis, and from 1992 to 1996 for the Asian crisis.
- Independent variables use the four-year periods of 1991-1994 for the Mexican crisis and 1993-1996 for the Asian crisis.
- Independent variables use the three-year periods of 1992-1994 for the Mexican crisis and 1994-1996 for the Asian crisis.
- Independent variables use the two-year periods of 1993-1994 for the Mexican crisis and 1995-1996 for the Asian crisis.

Table 9: Sensitivity Analysis of the Result to Different Thresholds of Real Exchange Rate Appreciation

	Independent Variables	15-percent threshold <sup>b</sup>	10-percent threshold <sup>a</sup> <i>Benchmark</i>	7-percent threshold <sup>c</sup>	5-percent threshold <sup>d</sup>	3-percent threshold <sup>e</sup>
b1	Constant	-2.75 (2.23)	-3.03 (1.90)	-3.11 (2.01)	-3.43 (2.02)	-4.87 (1.97)
b2	COM4 with an absence of high reserves	-3.41** (1.79)	-3.93* (0.84)	-2.82* (0.73)	-2.84* (0.72)	-2.64* (0.54)
b3	Lending booms with an absence of high reserves	0.27* (0.05)	0.22* (0.04)	0.20* (0.05)	0.20* (0.05)	0.19* (0.05)
b2+ b4	COM4 with high reserves	-1.01	-0.69	-0.08	-0.39	-0.46
b3+ b5	Lending booms with high reserves	0.01	0.01	0.01	0.01	0.02
Summary Statistic						
	R-Squared	0.38	0.56	0.5	0.51	0.57
	Adj R-Squared	0.32	0.52	0.46	0.46	0.53
Addendum: Walt Test						
	Ho: b2+b4 = 0	p-value 0.90	p-value 0.58	p-value 0.91	p-value 0.51	p-value 0.38
	Ho: b3+b5 = 0	p-value 0.69	p-value 0.66	p-value 0.61	p-value 0.60	p-value 0.57

Note: Standard errors are shown in parenthesis. One asterisk (\*) indicates statistical significant at a 5 percent level. Two asterisks (\*\*) indicate statistical significant a 10 percent level.

a. In the benchmark regression, the COM4 variable is defined as the current account deficits that is financed by financial flows only if the real exchange rate appreciation is greater than 10-percent threshold.

b,c,d,e 15-percent, 7-percent, 5-percent and 3-percent thresholds of real exchange rate appreciation are used to calculate the COM4 variable.

Table 10: Sensitivity Analysis of the Results to Defining the High-reserve Dummy

Estimated Coefficient	Independent Variables	First Quartile <sup>a</sup> <i>Benchmark</i>	Second Quartile <sup>b</sup>	Third Quartile <sup>c</sup>	Dummy for Short-term Debt <sup>d</sup>
b1	Constant	-3.03 (1.90)	-1.53 (1.89)	-0.51 (2.08)	-0.68 (1.92)
b2	COM4with an absence of high reserves	-3.93* (0.84)	-4.24* (1.13)	-7.45 (5.65)	-4.96* (1.31)
b3	Lending booms with an absence of high reserves	0.22* (0.04)	0.22* (0.06)	0.16 (0.28)	0.21* (0.07)
b2+b4	COM4 with high reserves	-0.69	-0.72	-1.63* (0.28)	-0.51
b3+b5	Lending booms with high reserves	0.01	0.02	0.04	0.02
Summary Statistic					
	R-Squared	0.56	0.55	0.48	0.54
	Adjusted R-Squared	0.52	0.51	0.44	0.50
Addendum:Wald Test					
	Ho: b2 + b4 = 0	p-value 0.58	p-value 0.47	p-value 0.06	p-value 0.60
	Ho: b3 + b5 = 0	p-value 0.66	p-value 0.47	p-value 0.15	p-value 0.27

Note: Standard errors are shown in parenthesis. One asterisk (\*) indicates statistical significant at a 5 percent level. Two asterisks (\*\*) indicate statistical significant a 10 percent level.

- In the benchmark regression, the dummy for high reserves(D=1) is assigned to a country that its ratio of M2 to reserves is below the lowest quartile of the sample. The lowest quartile is 2.18 for the 1994 sample, and 2.7 for the 1997 sample.
- The dummy for high reserves(D=1) is defined when a country's ratio of M2 to reserves is below the second quartile, i.e., 4.05 for the 1994 sample, and 4.14 for the 1997 sample.
- The dummy for high reserves(D=1) is defined when a country's ratio of M2 to reserves is below the top quartile, i.e., 6.12 for the 1994 sample, and 5.77 for the 1997 sample.
- The dummy for high reserves(D=1) is defined when a ratio of short-term debts to foreign reserves is below one.

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## Data Appendix

-Crisis Index (IND) is an indicator-weighted average of the exchange rate change with respect to the U.S. dollar minus the percentage change in foreign reserves. An increase in the index corresponds to a more severe crisis. We use November 1994 as the initial point for the Mexican crisis and June 1997 as the initial point for the Asian crisis and a later month as the end point. Each of the two components is weighted equally. The exchange rate (line ae) and the reserves (line l.d) data are available from IFS CD-ROM

-Real Exchange Rate Appreciation is the percentage increase in the real effective exchange rate index from 1990 to 1994 for the Tequila crisis and 1992 to 1996 for the Asian crisis. A rise in the index means the real exchange rate appreciation. The real effective exchange rate index is from the JP Morgan real exchange rate database.

-GDP is the gross domestic product. The GDP data are from IFS CD-ROM (line 99b)

-Current Account is the average share of current account to GDP between 1990 and 1994 for the Mexican crisis and between 1992 and 1996 for the Asian crisis. The current account data are from IFS CD-ROM (line 78 al).

-Government Budget is the average share of budget account to GDP between 1990 and 1994 for the Mexican crisis and between 1992 and 1996 for the Asian crisis. The government budget account data are from IFS CD-ROM (line 80). For Hong Kong, the government budget account data are from Hong Kong Census and Statistics.

-Lending Booms are the percentage change in the ratio of claims on the private sector to GDP from 1990 to 1994 for the Mexican crisis and from 1992 to 1996 for the Asian crisis. The claims on the private sector data are from IFS CD-ROM (line 32d).

-The Dummy for high reserves is one when a ratio of M2 to reserves is below the lowest quartile of the sample. This ratio is calculated for November 1994 for the Mexican crisis and June 1997 for the Asian crisis. The M2 data are from IFS CD-ROM (line34 plus line 35). Alternatively, the dummy for high reserves is one when a ratio of short-term external debts to reserves is less than one. This ratio is calculated for December 1994 for the Mexican crisis and June 1997 for the Asian crisis. The short-term external debt data are available at <http://www.oecd.org/dac/debt/>.