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To:       Members of the Executive Board

From:     The Secretary

Subject:   **Anticipating Balance of Payments Crises—The Role of Early Warning  
Systems**

Attached for consideration by the Executive Directors is a paper on the role of early warning systems in anticipating balance of payments crises, which will be brought to a seminar discussion on a date to be announced. Issues for discussion appear on pages 33 and 34.

Mr. Borensztein (ext. 37679), Mr. Berg (ext. 37933), or Ms. Pattillo (ext. 37319) is available to answer technical or factual questions relating to this paper prior to the seminar discussion.

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**Anticipating Balance of Payments Crises:  
The Role of Early Warning Systems**

Prepared by the Research Department

Approved by Michael Mussa

December 16, 1998

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## I. INTRODUCTION

1. Recent years have witnessed an increase in the frequency of currency and balance of payments crises in developing countries, stimulating research on their prediction.<sup>1</sup> Clearly it would be desirable to have a system for identifying looming crises so that steps could be taken to avoid them. This is already an objective of IMF surveillance, though the Article IV consultation process is focused more on identification and adjustment of undesirable policies than on the prediction of crises per se. With the increasing liberalization of capital movements and the globalization of financial markets, unsustainable policies may at times be disciplined by an early reaction of financial markets, while on other occasions, they may be exacerbated by strong capital inflows that are later reversed as investor sentiment suddenly changes. The resulting crisis may itself be associated with economic disruption and welfare losses that go beyond those justified by the economic fundamentals, making crisis prediction and prevention an important objective. The aim of this paper is to assess the progress of attempts to develop systematic empirical frameworks for predicting balance of payments crises, and to consider how such frameworks could be used in Fund surveillance.

2. A number of projects were initiated after the Mexican crisis of December 1994 to design an early warning system (EWS), including some research undertaken in the Fund.<sup>2</sup> These efforts have multiplied since the onset of the Asian crisis.<sup>3</sup> EWSs apply some statistical method to predict the likelihood that a country will face a currency or balance of payments crisis, defined in a precise way, over a given time horizon.<sup>4</sup> The EWS frameworks focus on economic and financial variables that are likely to provide an early indication of a vulnerable balance of payments position or unsustainable exchange rate level. These variables typically include indicators of domestic macroeconomic imbalances and banking sector weakness,

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<sup>1</sup>A currency crisis usually refers to situations in which speculative attacks force a sharp devaluation. This paper focusses on the broader concept of balance of payments crises, which include situations in which speculative attacks force a sharp drop in international reserves and/or a sharp devaluation. Furthermore, although most of the theoretical literature focusses on attacks against a pegged exchange rate regime, this paper takes a broader view, considering also the possibility of speculative attacks against more flexible regimes, such as managed floats.

<sup>2</sup>Most notably, Kaminsky, Lizondo and Reinhart (1998). More detailed references are provided in Sections III and IV.

<sup>3</sup>In addition to published research, a number of institutions, including the Federal Reserve Board, the Federal Reserve Bank of New York, and the Bank for International Settlements, are developing some form of EWS to complement their analysis of financial markets.

<sup>4</sup>While all models try to anticipate exchange rate movements, some of them take a broader focus and try to anticipate both currency crashes and failed attacks. The latter are evidenced by losses in international reserves and/or sharp increases in domestic interest rates.

such as fiscal deficits and domestic credit growth; of overvaluation of the exchange rate, such as measures of relative prices or costs, the current account deficit, and export growth; and of external vulnerability and contagion, such as external liabilities relative to international reserves and the incidence of crises in other countries. In sum, the range of possible variables encompasses measures of both the fundamentals of the domestic economy and the vulnerability to changes in market sentiment and the global environment.

3. In order to predict crises, it is necessary to have a clear understanding of their causes. There are essentially two competing strands of theories, called first and second generation models, that are reviewed in Appendix I. The first focusses on the consequences of excessive credit growth in provoking a depletion of foreign exchange reserves, making a devaluation inevitable. The second emphasizes the choices that the policymaker faces in defending a peg: if the costs in terms of unemployment or financial sector fragility of using interest rates to defend the exchange rate are too high, the authorities may choose to devalue. The possibility that crises may be the result of self-fulfilling expectations may make them difficult, if not impossible, to predict in some cases.

4. To be most useful to the Fund, an EWS should try to identify situations that pose a distinct risk of a crisis affecting the external payments of a country or a large devaluation of its currency. But what are the events or situations that a system should provide warnings about? In some cases, like the abandonment of a peg, a collapse in the value of the domestic currency or a default in international payments, there is no ambiguity in identifying the event. But should the definition also include cases that involve sizable but unsuccessful currency attacks, such as Argentina in 1995 or Brazil in 1997? The Fund should be alert to any situation in which the external position of a country is vulnerable; this also includes currency attacks that ultimately result in "close calls" but no devaluation. Adopting this broader definition of crisis may make the problem of prediction more difficult, to the extent that failed attacks are truly different from currency collapses, but the broader measure will be more useful to policymakers. The specific empirical implementation of alternative crisis definitions is discussed in Section III below.

5. How well have existing EWSs done in predicting currency or balance of payments crises? The performance of three representative frameworks (plus an extension developed by staff) is examined in Section IV. The short answer is, they have had mixed success. The predictions from the most promising models contain substantial information about the risks of crisis, but they often provide false alarms. A representative EWS model produces a warning signal (indication that a crisis is approaching) in about 50 percent of the cases in which it should because a crisis did indeed happen at some point over the following two years. This means, in a typical case, that during the two years before a crisis the model issued a warning signal in about 12 of the 24 months. But the warnings issued by the typical EWS model are not very reliable. About 60 percent of the times that the typical model issued a warning, no crisis happened during the following two years.

6. Looking specifically at the performance in relation to the Asian crisis of some representative models that were designed and estimated before 1997, these models tend to

perform somewhat more poorly than in the period for which they were designed and estimated. The percentage of correct warning signals during the two years prior to the crises of 1997 drops to about 34 percent. However, the number of false alarms (when the model indicated that a crisis was approaching but no crisis took place during the following two years) also drops to about 51 percent.

7. Although it is possible, in principle, to calibrate models to forecast a larger fraction of the emerging crises, this would imply a cost in terms of the reliability of the signals. That is, the number of false alarms, predicted crises that do not materialize, rises as the number of missed crises falls. The precise calibration of the EWS thus depends on the relative cost associated with each type of error. In principle, since the purpose of an EWS is to anticipate currency crises, one would prefer a specification that is fairly sensitive to symptoms and would not fail to issue warnings very often when a crisis is indeed approaching. But one should be aware that, in such cases, even the best-performing model is bound to produce its share of false signals: currency attacks, and even currency collapses, that are predicted by the model but will fail to materialize. These trade-offs need to be considered in applying an EWS to surveillance work, and are raised as an issue for discussion in Section V.

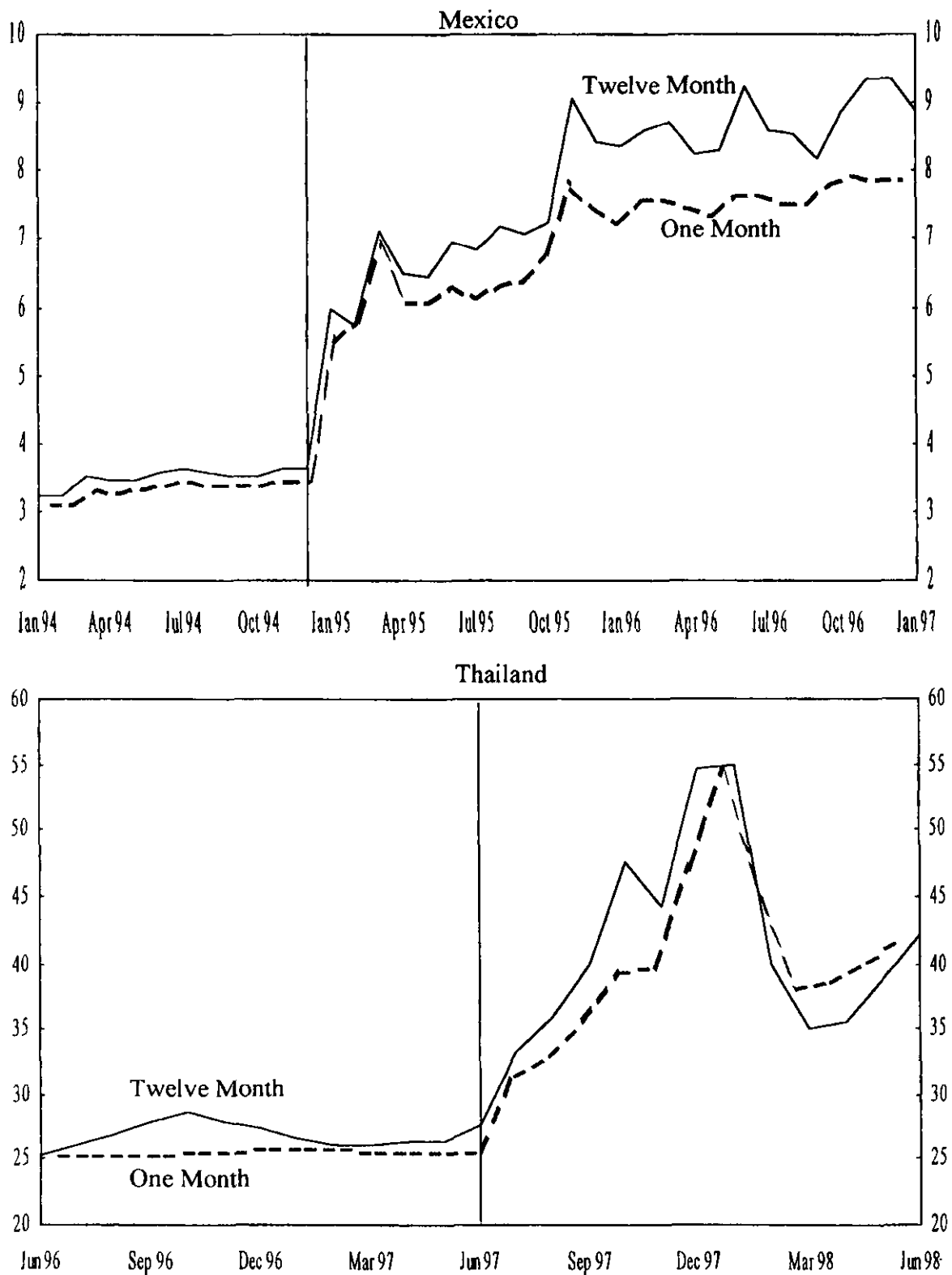
8. What is the standard against which to judge the value of forecasts generated by an EWS? Available measures of expectations by market participants and interest differentials display a poor record with respect to recent events in anticipating crises. For example, a direct measure of exchange rate expectations from the surveys carried out by the Financial Times Currency Forecaster (which surveys banks, multinational companies and professional forecasters on a monthly basis) suggests that markets had little inkling of the approaching crises in Mexico in 1994, or Thailand in 1997 (Chart 1).<sup>5</sup> The 30-day ahead exchange rate forecast showed virtually no increase in expectations of a devaluation in the months just before the currency collapsed, while for Mexico, the 12-month ahead expectations turned more pessimistic in the second half of 1995 and in 1996, when Mexico was actually already emerging from the crisis. In the Asian crisis, countries' expectations of exchange rate depreciation went up sharply in October 1997 when markets in Hong Kong and throughout the region displayed significant turbulence, but abated in November 1997, just before the collapse of the Korean won and renewed weakness of some other currencies in the region.

9. As discussed in Section V, this suggests that, although an EWS will hardly be infallible, it can make a contribution to the Fund's economic surveillance activity. While EWSs look at many of the same economic and financial variables that are the focus of traditional Fund surveillance, their strength is that they process the information contained in the rather large number of relevant variables in a systematic way that maximizes their ability to predict currency and balance of payments crises, based on the historical experience of a large number of countries. Often an EWS can translate this information into a composite measure of vulnerability. Being based on a well-defined methodology, it is less likely to be

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<sup>5</sup>The chart is from Goldfajn and Valdés (1998), where a more systematic analysis of exchange rate expectations is conducted. See also Agénor and Masson (forthcoming).

Chart 1  
Exchange Rate Expectations



Source: Surveys by Financial Times Currency Forecaster.



clouded by preconceptions about the expected economic performance of particular countries. Furthermore, an EWS can be a useful tool to rank the relative vulnerability of a group of countries, something that is more difficult to assess with more traditional surveillance tools.<sup>6</sup>

10. An earlier precedent for the systematic use of economic indicators in surveillance are the 1986/87 attempts to assess the sustainability of exchange rates among the major industrial countries. At various meetings of the Executive Board there was broad support for the use of economic indicators, but also concern about implementing a system that would mechanistically require countries to adopt policy adjustments when indicators reached some thresholds. In addition, the exercise did not have a single focus; instead, the objective was to judge the broad sustainability and desirability of the fiscal and monetary policy stances of the major industrial countries. In the event, an indicator-based system for the adjustment of macroeconomic policies was not implemented, but the use of indicators to facilitate discussions on policy coordination issues in the G7 and other forums was made more systematic.<sup>7</sup>

## **II. WHAT CAUSES BALANCE OF PAYMENTS CRISES?**

11. The sudden collapse of exchange-rate pegs in the absence of an immediate major change in economic fundamentals can seem a clear proof of irrationality in foreign exchange markets. An important contribution of the academic literature on this topic was to dispel that notion, showing that a sudden run on foreign exchange reserves that forces the abandonment of a peg can be, for example, the natural outcome of an inconsistency between monetary and exchange rate policy or the rational response by investors to a shift in expectations regarding macroeconomic policies. Appendix I provides a selective review of the causes of currency crises that have been identified in the, by now extensive, theoretical literature. In this section, we look at the features of the main crisis episodes over the past 20 years and what they suggest about the origins and symptoms of approaching crises.

### **A. Different Episodes, Different Determinants?**

12. The survey of the literature on currency crises in Appendix I suggests the distinction between crises that are caused by a deterioration in fundamentals and those that result from self-fulfilling speculative attacks. But even for the latter, it is often the case that some

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<sup>6</sup>The staff's analysis of exchange rates among major countries is a model for the possible use of an EWS. The Coordinating Group on Exchange Rate Issues (CGER) identifies possible misalignments among major currencies by applying a systematic, globally consistent, and transparent quantitative framework to all countries (see SM/97/252). However, application of the CGER methodology is only a first step, which is supplemented on a case by case basis by a broader analysis of the macroeconomic situation.

<sup>7</sup>See EBS/86/127, EBS/86/282, EBS/87/135, and Crockett (1987).

weakness in the fundamentals of the economy makes the country vulnerable to the speculative attack and the authorities less inclined to defend an exchange rate parity. Thus, a critical step in designing an early warning system for balance of payments crises is to identify those weak or inconsistent fundamentals. The problem is that the relevant fundamentals may be different in each episode, reflecting either disequilibria in the trade or capital accounts, private or public sector imbalances, and shocks to the real or financial sectors of the economy. The challenge in designing a unified approach is then to take into account all the relevant potential indicators of approaching crises.

13. Indeed, the changes in global financial markets and in emerging market economies have had an important effect on the genesis of crises, as exemplified by the differences in the major crises of the past two decades. The debt crisis of the 1980s reflected a mix of external shocks and domestic macroeconomic imbalances that had developed behind the screen of the strong capital inflows of the previous years. External shocks included a deterioration in the terms of trade, the sharp rise in US dollar interest rates, and the global economic slowdown. The debtor countries faced domestic macroeconomic imbalances that included large fiscal deficits and currency overvaluation (see, for example, Cline (1995)). To these factors, Dornbusch, Goldfajn and Valdés (1995) add the mismanagement of capital inflows, especially through the provision of implicit or explicit exchange rate guarantees to private and state enterprise borrowers, in the context of pegged or predetermined exchange rates. It is noteworthy that problems related to domestic banking systems did not receive a prominent place in the analyses of the debt crisis of the 1980s.

14. The Mexican crisis of 1994/1995 suggested different explanations and different fundamentals. In this case, some observers pointed to self-fulfilling prophecies by market participants as being largely responsible for the collapse of the peso. But it was also recognized that an underlying vulnerability in the economy made the speculative attacks possible: large current account deficits as well as the debt management policy followed just before the crisis had led to the accumulation of sizable short-term foreign debt; furthermore, the rapid expansion in the domestic financial sector had created a situation of poor quality loan portfolios and heavy exposure to an exchange rate devaluation. Reflecting on the lessons to be extracted from the experience, observers believed that increasing transparency in economic data and creating new mechanisms to provide rapid financial support by the international community would be necessary to prevent the recurrence of Mexico-style crises.<sup>8</sup> It is interesting to note that banking sector problems again did not receive prominent attention among the causes of the crisis despite their noticeable role in the unfolding of the Mexican crisis.

15. The Asian crisis put financial markets in the forefront of attention. In most, if not all, of the affected Asian countries, traditional sources of fundamental imbalances were largely absent. The fiscal position was quite robust for all countries, and inflation had been moderate

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<sup>8</sup>See Summers (1995) and Calvo and Mendoza (1996).

or low for a number of years.<sup>9</sup> With the exception of Thailand, real exchange rates had not displayed any significant appreciation in the years leading to the crises, and although a slowdown in export growth had been recorded in some of the economies of the region since 1996, it had come after several years of very strong expansion. The loan portfolios of financial institutions, by contrast, had deteriorated significantly, and the corporate sector was excessively indebted and financially fragile, the result of years of poor lending and investment decisions. Indeed, weaknesses in the financial and corporate sectors seem to be the only common thread among all the affected countries in the region, though of course other countries also share those same problems. (See Krugman (1998), Kochhar and Stone (1998), Berg (1998), Radelet and Sachs (1998b)). There is also a strong presumption that contagion, somehow defined, also played a major role, to the degree that some of the affected economies might not have had a crisis at all were it not for the negative market reaction triggered by Thailand. Spillovers originating in financial markets, as well as herding behavior by investors (not only in terms of joining in the stampede out of a currency but also in their propensity to flee from other countries in the same region), appear to have played an important role in the Asian "contagion", in addition to more traditional channels related to trade.

## **B. Searching for Common Symptoms**

16. Even if the ultimate causes of balance of payments crises may differ to some extent from case to case, it might be possible to identify a common pattern in the development of crises that becomes detectable as the process starts to unfold. For example, international reserves may become dangerously low at some point in the development of a currency crisis, or the level of external debt commitments may become too high relative to the relevant available resources. Alternatively, movements in asset prices may also follow a common pattern in anticipation of currency crises, such as increased risk premia on the vulnerable currencies.

17. This suggests a general strategy for the identification of the variables to be used in an early warning system. First, an EWS should consider the evolution of the economic fundamentals implied by both the "traditional" (or first-generation), and the "modern" (or second-generation) models of balance of payments crises. The range of fundamentals is further broadened as a result of the development of international financial markets. In particular, signals of stress in the banking sector should also receive attention. Second, an EWS should also consider indicators of the likelihood of a successful defense of the currency in case of an attack, as a less vulnerable currency is not likely to suffer serious attacks. One useful indication is international reserves relative to foreign-currency or foreign-currency

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<sup>9</sup>But the fiscal situation would have been considered less favorably if allowance was made for the contingent liability of the government arising from the support to financial institutions that might become necessary. But even making such allowance, the fiscal position would not have suggested an unsustainable burden.

linked liabilities, and it could be supplemented by data on forward positions in foreign currency and available lines of credit or other contingency financing.

18. It is important to note that these two types of variables, fundamentals and vulnerability indicators, play essentially complementary roles. Countries with weak fundamentals but good liquidity would not stay in a strong position for long, and conversely, countries with relatively bad liquidity but sound fundamentals, while not immune to attacks from “uninformed” investors, are less likely to be attacked and more likely to be successful in defending an attack. Finally, it may be worthwhile to explore the inclusion of indicators of market sentiment, such as those extracted from asset prices or from developments in other countries that might trigger contagion, despite the difficulty in obtaining empirically meaningful measures.

### **III. ISSUES IN THE DESIGN OF EARLY WARNING SYSTEMS**

19. Much of the empirical work on currency crises has aimed to characterize the stylized facts in periods leading up to crises (event studies), or to test particular models of crises. Event studies, which assess whether the behavior of particular variables is discernibly different in the months before a crisis from average behavior during tranquil periods,<sup>10</sup> are systematic methods for the important first stages of “looking at the data.” A prominent example is the WEO (1998), which studies currency crises in 50 advanced and emerging market countries. There are many other studies that test different theoretical models of currency crisis, with either multiple- or single-country data. Early warning systems, in contrast, are not concerned with explanations of specific crises or tests of particular theories; instead, they focus on finding the best methods that can be used to forecast crisis probabilities.

20. An early warning system consists of a precise definition of crisis and a mechanism for generating predictions, including a set of variables that may help predict crises and a systematic method to obtain a prediction from those variables. Different models have followed different approaches to address a number of conceptual and practical issues that arise concerning both the definition of crisis and the design of the method to predict them. The most important issues concern the definition of crisis, the methodology to apply, and the choice of variables to serve as predictors.

#### **A. What Are We Trying to Predict?**

21. In the theoretical work discussed in Section II, currency crises are typically characterized by sudden attacks on a pegged exchange rate regime. A “failed” attack may result in reserve losses or higher interest rates but no devaluation, while a successful attack

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<sup>10</sup> Eichengreen, Rose and Wyplosz (1995), Frankel and Rose (1996), Milesi-Ferretti and Razin (1998) and Kaminsky and Reinhart (1996) use event studies in addition to other approaches. Also see Moreno (1995).

results in a step devaluation or a flotation and depreciation, perhaps after reserve losses and/or interest rate increases. In practice, exchange rate pegs subject to speculative attack include not only fixed rates but also more-or-less managed exchange rates that may fluctuate or trend before the crisis. The need to systematically distinguish crises from other movements in exchange rates and reserves implies that translating the concept of speculative attacks into an empirical definition of crises is not straightforward.

22. Models that attempt to predict only successful attacks define a currency crisis as a sufficiently large change in the nominal or real exchange rate over a short period of time. For example, in their 1996 study, Frankel and Rose defined a currency crisis as a change in the nominal exchange rate of over 25 percent in one year, using annual average data. Some approaches attempt to predict speculative attacks, rather than only currency crises. That is, they model failed as well as successful attacks. For example, Kaminsky, Lizondo and Reinhart (1998) combine information on reserve changes and exchange rate changes into a crisis index.<sup>11</sup> Models that also predict failed attacks are more useful to policy-makers since they are interested in anticipating any speculative attacks, which, of course, ex ante cannot be known as failures or successes. Whether or not a devaluation occurs depends on the resolve of the authorities and the measures they take.

23. A difficulty with most empirical definitions of crisis arises from the need to distinguish currency crises from nominal devaluations associated with high inflation. Frankel and Rose restricted the definition of crisis to include only cases when the nominal devaluation was at least 10 percent higher than the previous year. This definition does not work very well in cases of high inflation; for example, it would consider a country to have a crisis if it had a constant annual inflation rate of 80 percent and a nominal depreciation of 74 percent one year and 85 percent the next. Kaminsky, Lizondo and Reinhart (1998) follow an alternative approach that basically takes a different benchmark to define a crisis in periods of very high inflation (observations in which the country had a six-month inflation rate above 150 percent).

## **B. How to Generate Predictions**

24. Once a set of crises has been identified, the question of what methodology to use to predict the crises arises. One can divide the possible frameworks into three groups. The first approach is to analyze a particular crisis episode or set of crises that occur together in time. Sachs, Tornell and Velasco (1996), for example, analyze the incidence of currency crisis across a group of countries after the Mexican crisis as a function of a variety of pre-crisis factors. This approach cannot hope to shed light on the timing of crises. Rather, it may answer the question of which countries are most likely to suffer serious attacks in the event

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<sup>11</sup>Studies analyzing advanced economies, such as Eichengreen et al. (1995), typically combine information on interest rate changes, reserve changes and exchange rate changes into an index of speculative attack. This is generally not possible for developing countries because historical data on market interest rates are often not available.

of an unfavorable change in the global environment. The justification for this approach is twofold. First, the timing of a crisis may be much harder to predict than its incidence across a group of countries. Knowing which country is most vulnerable in the event of a worldwide shock could still be useful information. Second, by focussing on a set of crises occurring at one particular time, the model avoids the problem posed by the possible changes in the determinants of crisis episodes over time. However, although this type of model may help to identify more vulnerable countries, its specification limits its usefulness for predicting future crises.<sup>12</sup>

25. The remaining two approaches examine data on a sample of countries through time (that is, a "panel" of data). The "indicators" approach of Kaminsky, Lizondo and Reinhart (1998) considers a number of indicator variables (such as the degree of real exchange rate overvaluation) and calculates threshold values such that the indicator issues a "signal" of forthcoming crisis when its value is above this threshold. The third method, exemplified by Frankel and Rose (1996), uses a regression in which the dependent variable takes a value of unity when there is a crisis and zero otherwise (called a probit regression). The independent variables are the various potential predictors suggested by economic theory.<sup>13</sup>

26. There are important additional design issues for methods such as the indicators and probit regression approaches that attempt to predict both the timing and the cross-country incidence of crises. First, a choice must be made regarding how far in advance the prediction is to be made. Kaminsky, Lizondo and Reinhart, for example, attempt not to predict the exact timing of the crisis but rather the likelihood that a crisis will occur some time in the next 24 months. Although this relatively wide time window could be considered a drawback of the method, it may be a realistic approach, particularly in light of the analysis in Section II that suggested that the timing of crises may not be predictable at all in conditions of multiple equilibria and self-fulfilling attacks.

27. A further question involves what set of historical crises to use in calibrating the model. The inclusion of more years and more countries would in principle allow more precise

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<sup>12</sup> Glick and Rose (1998) look at crises in several cross-sections of countries in years of widespread currency crises. They find that the incidence of crisis across countries is partly explained by trade linkages with the country that initiated the round of contagion (for example, Mexico in 1994/1995). This would not help predict and does not even help with relative vulnerabilities, unless one knows which country initiates the contagion.

<sup>13</sup> A recent development is models produced by several investment banks to forecast the probabilities of large currency depreciations. The banks' studies seek to provide information that could be profitable to participants in foreign exchange markets, often using models similar to those in the third category above. (See "Event Risk Indicator Handbook" of J.P. Morgan, "Emerging Markets Risk Indicator" from Credit Suisse First Boston, "Currency Jump Probability" measure of Lehman Brothers, and "Early Warning System" of Citicorp).

estimation of the relationship between the various predictive variables and subsequent crises. However, the crises used to estimate the model must be reasonably similar to the crises the model is trying to predict. Different approaches can be distinguished along this dimension. The Sachs, Tornell and Velasco (1996) cross-section approach represents one extreme, in which no historical information is used, with the model being fit to only one set of crises occurring in a fairly small sample of similar countries at one point in time. At the other extreme are the approaches of Kaminsky, Lizondo and Reinhart (1998) and Frankel and Rose (1996). Both use data from 1970. Frankel and Rose, in addition, use data from as many countries as possible, over one hundred. Evidence suggests that this sample is too large and diverse, in that the impact of various determinants on the probability of crises in a smaller set of more homogeneous developing countries can be more reliably estimated.<sup>14</sup>

### **C. What Variables to Include, and How to Measure Them**

28. The discussion of the nature of currency crises in Section II suggests a large number of variables that might help predict currency crises. Indeed, a variety of predictive variables have been considered for inclusion in early warning systems. These variables can be classified into several groups. First, measures of the exchange rate itself, typically assessing the overvaluation of the real exchange rate compared to a trend or its long-term average. Second, various measures of macroeconomic imbalances, such as domestic credit expansion and output growth, in the spirit of the “first generation” crisis models discussed above. Third, variables designed to capture unsustainable external positions, such as reserve adequacy measures, external debt, and the size of the current account deficit. Fourth, problems in the domestic financial sectors; given the difficulties in obtaining measures in a consistent way across countries and time, rather crude measures have been applied such as growth rates and levels of domestic credit as indicators of over-leverage. Fifth, indicators that reflect market expectations, such as interest rate differentials or the forward exchange rate.<sup>15</sup> Sixth, financial market contagion variables, such as the number of crises in recent months in other countries.<sup>16</sup>

29. For the purpose of estimation of an early warning system, a given variable must be reasonably comparable across time and countries. Many factors that experience suggests might help predict crises are not easily measured and do not meet that standard. Perhaps the most glaring examples involve data regarding the health of financial systems, such as rates of non-performing loans and capital adequacy. Similarly, variables may be badly mismeasured

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<sup>14</sup>See Milesi-Ferretti and Razin (1998) and Berg and Pattillo (1998).

<sup>15</sup>This approach has the disadvantage that it cannot do better than the market itself, whereas one of the goals of an warning system is to provide *early* warning. As we saw in Section II, market expectations of crisis typically do not rise until very shortly before the crisis.

<sup>16</sup>Another potentially important category of variables, not included in the studies considered here, are political variables, such as the timing of elections.

for various reasons. Accurate and comprehensive information on short-term external debt of the private sector, for example, is not available for most countries.<sup>17</sup> These measurement or availability problems imply that it is difficult to incorporate this information into early warning systems that are calibrated using historical episodes.

#### IV. HOW WELL DO THE MODELS PERFORM?

30. Recent work claiming success in predicting crises has focussed almost exclusively on in-sample prediction.<sup>18</sup> There is an important danger in focussing on this type of evaluation as it may overestimate the ability of the models to predict future crises. The implementation of each model involves using historical data to estimate the model, that is to decide exactly how much weight to give to each different candidate predictive variables. The danger is that, as emphasized in Section II, different sets of crises may be fundamentally different. Models fitted over historical data may not provide much guidance for the prediction of subsequent crises. In order to guard against overestimating the usefulness of these crisis prediction models, we therefore emphasize the testing of these models “out-of-sample”, that is, in predicting crises that occurred after the models were formulated and estimated.

31. The Asia crisis is a natural testing ground for the out-of-sample performance of crisis prediction models. The large number of crises in 1997 came largely as a surprise to most observers, suggesting a possible role for prediction models. These crises contained a variety of new elements as well as some important points of continuity with previous crises. Moreover, a number of crisis prediction models had been elaborated prior to the Asian crisis, inspired by the Mexican crisis of 1994. Thus, this section addresses the question: if one had used these models in late 1996, how well armed would one have been to predict the Asia crisis?

32. To evaluate the performance of EWSs, one study representative of each of the three types of approaches to predicting currency crises that were identified above is examined in depth. These studies are among the most well-known and promising based on their success within sample. All these models were formulated prior to 1997, so that their application to the Asia crises is truly “out of sample.” In addition, the results from a model currently under development in the Developing Country Studies Division of the Research Department (DCSD)<sup>19</sup> which combines features of the other three approaches, are also presented. Out-of-sample tests of this model can be performed only in the sense of estimating it using data up to 1995 and then checking how well it fares in predicting events in 1997. This is

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<sup>17</sup>Within the Fund, the Interdepartmental Task Force on External Debt and Reserves has been working with area departments to examine and improve the coverage of external debt data and the dissemination and comprehensiveness of data on reserves.

<sup>18</sup>Partial exceptions are Tornell (1998) and Kaminsky (1998).

<sup>19</sup>The findings in this chapter are based on Berg and Pattillo (1998).



not a “pure” out of sample test, however, in that the model was inevitably formulated, and, in particular, variables chosen, with the benefit of hindsight regarding the Asia crisis. The models have the following features.

- Kaminsky, Lizondo, and Reinhart (1998) (KLR) develop an early warning system for currency crises based on a variety of monthly indicators that signal a crisis whenever they cross a certain threshold value. A variable-by-variable approach is chosen so that a surveillance system based on the method would provide assessments of which variables are “out-of-line”. The information from the separate variables is combined to produce a composite measure of the probability of crisis.
- Frankel and Rose’s (1996) (FR) probit regression model of currency crashes analyzes a broad set of potentially important variables. Motivated by the Mexico crisis, the study tests in particular the hypothesis that certain characteristics of capital inflows are associated with currency crashes. Their use of annual data permits them to look at these variables, as well as others that are available only at annual frequency.
- Sachs, Tornell, and Velasco (1996) (STV) restrict their attention to a cross-section of countries in 1995. They test whether the incidence and severity of crisis following the Mexico devaluation can be explained by a particular set of fundamentals, where the framework assumes that countries with weak fundamentals and low reserves were particularly vulnerable to the effects of Mexico’s devaluation.<sup>20</sup>
- The DCSD model, in the spirit of the KLR approach, uses monthly data to determine which variables contribute to the probability of a crisis occurring within the following 24 months. The concept is to take maximum advantage of the predictive power provided by the monthly indicators suggested by KLR, as well as some additional variables, by using them in an econometric framework similar to that of FR (a probit regression).

33. The most basic evaluation of the models is to gauge how well they perform in predicting crises in-sample, that is, when applied to the historical data that was used to formulate the model. The discussion below is based on estimation of the KLR, STV and DCSD models on a common sample of 23 emerging market economies through April 1995, and on a sample of 41 developing countries for FR.<sup>21</sup>

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<sup>20</sup>Their approach has also been applied to the Asia crisis. Tornell (1998), Sachs, and Radelet (1998b) and Corsetti, et al. (1998) estimate variants of STV for 1997. IMF (1998) constructs a composite indicator of crisis based on the STV approach and argues that it accords well with the pattern of country experience in the Asia crisis.

<sup>21</sup>The countries in the different samples are listed in a footnote to Table 2 below.

### A. Kaminsky-Lizondo-Reinhart Model

34. Since the KLR approach assesses the signaling properties of indicators one at a time, the effectiveness of the approach can be examined by determining the extent to which each individual indicator is useful in predicting crises. Of the 15 indicators considered (see Table 1), 8 are found to be informative, in that crises are more likely to occur when the indicator signals than when it does not. These “good” indicators are: deviations of the real exchange rate from trend, the growth in the ratio of M2 to international reserves, export growth, growth of international reserves, “excess” M1 balances, growth in domestic credit as a fraction of GDP, the real interest rate, and the change in terms of trade.

35. Table 1 shows various measures of the effectiveness of these indicators. First, consider the observations that are in fact followed by a crisis within 24 months. Column (1) shows the fraction of these observations for which the indicator is signaling a crisis. Next consider false alarms, that is signals that are not followed by a crisis within 24 months. Column (2) shows the fraction of signals that are false alarms. A perfect indicator would obtain 100 percent in column (1), implying that a signal was issued every month during the 24 months prior to each crisis, and 0 in column (2), indicating that all signals that were issued were indeed followed by a crisis within 24 months. Clearly, some indicators are better than others. The best eight would seem to contain useful information; for these indicators, the issuance of a signal implies a probability of crisis higher than that implied by the actual incidence of crises over the sample, as shown in column (4). On average, these good indicators signal a crisis 18 percent of the time a crisis does in fact ensue.<sup>22</sup> A large share of the signals are bad signals: 71 percent of the times that the average good indicator signaled, it was not followed by a crisis within 24 months.

36. These results appear to be poor: signals are mostly false alarms, while most pre-crisis months are not signaled. However, these signals do carry substantial information about the probability of crisis. When an indicator signals, a crisis ensues more often than when there is no signal. For example, 47 percent of the time the real exchange rate signals, a crisis ensues within 24 months, as column (3) of Table 1 shows. This probability of crisis is much higher than the average frequency of crises in the sample, so that the real exchange rate signal does increase the expected probability of crisis, as shown in column (4).

37. Clearly, it would be desirable to combine the information from the various indicators. To this end, the indicators can be aggregated into a composite index that measures the probability of crisis for each country at every point in time (see Kaminsky, 1998). Table 1 showed that some indicators are much better predictors than others. Thus, each indicator is weighted by a measure of its reliability in predicting crises. The performance of this approach can be assessed systematically by looking at various goodness-of-fit measures. (The Box

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<sup>22</sup>An alternative, less exacting benchmark would be to consider a crisis as correctly called whenever an indicator signaled **at least once** within the 24 months prior to each crisis. On this measure, the average good indicator signaled before 66 percent of the crises.

Table 1. Performance of Kaminsky-Lizondo-Reinhart (KLR) Indicators

	Good Signals as Share of Times the Indicator should be Signaling 1/ (1)	False Alarms as a Share of Signals 2/ (2)	Probability of Crisis Given a Signal (3)	Increase in Expected Probability if Indicator Signals (in percentage points) 3/ (4)
Real exchange rate 4/	26	53	47	29
M2/reserves growth rate	26	65	35	17
International reserves growth rate	18	67	33	15
Export growth rate	15	73	27	9
Excess M1 balances	15	73	27	9
Real interest rate	15	78	22	4
Domestic credit/GDP growth rate	19	78	22	4
Terms of trade growth rate	10	80	20	1
Lending rate/deposit rate	9	85	15	-1
M2 multiplier growth rate	17	85	15	-2
Industrial production growth rate	13	82	18	-2
Import growth rate	12	84	16	-2
Real interest differential	14	86	14	-4
Stock price index growth rate	13	87	13	-6
Bank deposit growth rate	7	88	12	-6
Average for 8 "good" indicators 5/	18	71	29	11

Sources: Berg and Pattillo (1998), and staff calculations.

1/ A good signal is a signal that is followed by a crisis within 24 months.

2/ A false alarm is a signal that is not followed by a crisis within 24 months.

3/ Probability of crisis given a signal less the unconditional probability of crisis in the sample

4/ Deviation from trend.

5/ "Good" indicators are those for which signals are in fact associated with a higher frequency of crisis. That is, for "good" indicators, a signal implies a probability of crisis higher than that implied by the actual incidence of crisis over the sample.

### Box 1. Summary Measures of Model Performance

One of the difficulties in assessing the predictive success of EWSs is that the models generally produce an estimated probability of crisis, which cannot be compared with the unobservable actual probability of crisis but only with the occurrence or not of a crisis. Yet it is possible to compute a number of measures of how well model probabilities correspond to the subsequent incidence of crises (**goodness-of-fit**). The first step is to convert predicted probabilities of crisis into **alarms** or **signals** that a crisis will ensue within the following 24 months (assuming that 24 months is the model's horizon). A signal is defined as a predicted probability of crisis above some threshold level (the **cut-off threshold**). Then, each **observation** (a particular country in a particular month, for example Thailand in December 1996) is categorized as to whether it is predicted to be a pre-crisis month and also according to whether it is an actual pre-crisis month.

It is a **predicted pre-crisis observation** if the predicted probability of crisis is above the threshold, otherwise it is a **predicted tranquil observation**. If a crisis in fact ensues within 24 months of the observation in question, it is an **actual pre-crisis observation**; otherwise it is an **actual tranquil observation**.

The table shows how the signals from the from the DCSD model discussed in Section IV and presented in Table 5 compare to actual outcomes, for the out-of-sample period May 1995 through December 1997. It uses a cut-off threshold for calling a crisis of 25 percent.

The number in each cell represents the number of observations that satisfy the criteria listed in the rows and columns. Thus, a given observation is either followed by a crisis within 24 months or it is not, so it belongs in either the tranquil column or the pre-crisis column. The model either generates a probability of crisis below 25 percent or it does not, so it is counted in either the tranquil row or the pre-crisis row. For example, for the entire out-of-sample period and country sample, there were a total of 321 tranquil months, and for 259 of them the probability of crisis was below the 25 percent threshold. From this table the various measures of accuracy discussed in the text can be calculated:

Out-of-Sample Goodness-of-Fit: DCSD Model				
		Actual		
		Tranquil	Pre-Crisis	Total
Predicted	Tranquil	259	32	291
	Pre-Crisis	62	88	150
Total		321	120	441

- The **fraction of observations correctly called** (79 percent) is equal to the sum of **pre-crisis months correctly called** (observations which were followed by a crisis within 24 months for which a signal was issued) (88) and tranquil periods correctly called (259) divided by the total number of observations (441).
- The **rate of false alarms** as a share of signals (41 percent) is equal to the number of predicted crises not in fact followed by a crisis (62) divided by the total number of observations for which the model predicted a crisis (150).
- The **probability of a crisis given a signal** (59 percent) is equal to the number of observations for which a signal was issued and a crisis ensued (88) divided by the total number of signals issued (150). (This is the same as 100 minus the rate of false alarms.)
- The **probability of a crisis given no signal** (11 percent) is equal to the number of observations for which a signal was not issued and a crisis ensued (32) divided by the total number of observations during which no signal was issued (291). The difference between the probability of crisis given a signal and the probability of crisis given no signal is the increase in the risk of crisis associated with the issuance of a signal.

explains these measures in detail). For example, a natural question to pose is whether the estimated probability of crisis is above 50 percent prior to actual crises. Table 2 shows that the predicted probability of crisis was above 50 percent in 9 percent of the months between January 1970 to April 1995 when a crisis followed within 24 months. The model does correctly call almost all (99 percent) of the more numerous tranquil periods. One could consider a lower cutoff probability than 50 percent if there is relatively higher concern with missing crises and relatively lower concern with issuing false alarms. Using a 25 percent cutoff, for example, the model predicts a crisis in 46 percent of periods that it should.<sup>23</sup> Of course, this improvement in the fraction of crises correctly predicted comes at the expense of a lower fraction of tranquil periods correctly called.

38. Another way of looking at these goodness-of-fit statistics comes from taking the perspective of a decisionmaker who must choose a course of action based on these crisis predictions. An important question would be the incidence of false alarms—the fraction of times no crisis occurs when crises are predicted. When probabilities above 25 percent are said to be predicting a crisis, 65 percent of these crisis predictions precede non-crisis months. As we observed before, this high false alarm rate does not mean the estimated probabilities carry no information. Most of the time, the estimated probability of crisis is below 25 percent. Crises in fact follow these observations only 13 percent of the time. When the probability rises above 25 percent, crises are in fact more likely, ensuing 35 percent of the time.

### **B. Frankel-Rose Model**

39. The FR model was updated through 1996 using a 41 country sample that is comparable to the samples used in the other studies (the original study was based on a much broader sample of developing countries). The results show that the probability of a crisis increases when domestic credit growth is high, reserves as a share of broad money are low, the real exchange rate is overvalued, the fiscal and current account deficits are high, when an economy is more closed (measured by the share of exports and imports in GDP) and when foreign interest rates are high. In addition, some characteristics of capital inflows seem to matter. Low shares of concessional debt and FDI as a proportion of total debt increase the probability of crisis, as do high shares of debt issued by the public sector.

40. The goodness-of-fit statistics show that the model performs fairly well in generating predicted probabilities of crashes above 50 percent when a crash actually occurs (column 2 of Table 2). The model correctly predicts one-third of the crashes in the sample, with only a 26 percent incidence of false alarms. Using a threshold of 25 percent, correct predictions increase to 63 percent of the crashes, and false alarms to 52 percent. Thus, the Frankel-Rose model performs somewhat better than the KLR framework in predicting crises within sample.

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<sup>23</sup>More precisely, the model issued a signal in 46 percent of the months in the two years prior to each crisis.

Table 2. Predictive Power of Kaminsky-Lizondo-Reinhart (KLR), Frankel-Rose (FR) and Developing Countries Studies Division (DCSD) Models—In-Sample 1/

	Full-Sample		1986—95:4 Sample	
	KLR Weighted-Sum Based Probabilities	FR Probabilities	DCSD Probabilities w/o Short-Term Debt	DCSD Probabilities with Short-Term Debt
<b>Goodness-of-Fit: (cut-off probability of 50 percent)</b>				
Percent of observations correctly called	83	90	84	85
Percent of pre-crisis periods correctly called 2/	9	33	7	2
Percent of tranquil periods correctly called 3/	99	98	100	100
False alarms as percent of total alarms 4/	30	26	11	0
Probability of crisis given:				
An alarm 5/	70	74	89	100
No alarm 6/	17	10	16	15
<b>Goodness-of-Fit: (cut-off probability of 25 percent)</b>				
Percent of observations correctly called	75	86	78	81
Percent of pre-crisis periods correctly called 2/	46	63	48	39
Percent of tranquil periods correctly called 3/	81	89	84	88
False alarms as percent of total alarms 4/	65	52	63	64
Probability of crisis given:				
An alarm 5/	35	48	37	36
No alarm 6/	13	6	11	11

Sources: Berg and Pattillo (1998), and staff calculations.

1/ The KLR and DCSD models are estimated using a 23-country sample comprised of: Argentina, Bolivia, Brazil, Chile, Colombia, India, Indonesia, Israel, Jordan, Korea, Malaysia, Mexico, Pakistan, Peru, Philippines, South Africa, Sri Lanka, Taiwan Province of China, Thailand, Turkey, Uruguay, Venezuela and Zimbabwe.

The 41 country FR sample includes all of these countries except for Israel, Jordan, South Africa and Taiwan Province of China, plus the following 22 countries: Algeria, Botswana, Costa Rica, Côte D'Ivoire, Dominican Republic, Ecuador, Egypt, El Salvador, Guatemala, Hungary, Iran, Jamaica, Mauritius, Morocco, Oman, Panama, Portugal, Paraguay, Romania, Syria, Trinidad & Tobago and Tunisia.

2/ This is the number of pre-crisis periods correctly called (observations for which the estimated probability of crisis is above the cut-off probability and a crisis ensues within 24 months) as a share of total pre-crisis periods.

3/ This is the number of tranquil periods correctly called (observations for which the estimated probability of crisis is below the cut-off probability and no crisis ensues within 24 months) as a share of total tranquil periods.

4/ A false alarm is an observation with an estimated probability of crisis above the cut-off (an alarm) not followed by a crisis within 24 months.

5/ This is the number of pre-crisis periods correctly called as a share of total predicted pre-crisis periods (observations for which the estimated probability of crisis is above the cut-off probability).

6/ This is the number of periods where tranquility is predicted and a crisis actually ensues as a share of total predicted tranquil periods (observations for which the estimated probability of crisis is below the cut-off probability).

### **C. Sachs-Tornell-Velasco Model**

41. STV argue that a key feature of the 1995 crises was that the attacks only hit hard at already vulnerable countries. Thus, countries with overvalued exchange rates and weak banking systems<sup>24</sup> were subject to more severe attacks, but only if they had low reserves relative to monetary liabilities (so that they could not easily accommodate capital outflows) and weak fundamentals (so that fighting the attack with higher interest rates would be too costly).

42. Using the 23-country common sample (still for the 1995 crises), the estimated STV model fits the data only moderately well. The main hypotheses receive mixed support: a depreciated real exchange rate lowers crisis severity only for countries with low reserves and weak fundamentals, but the effect of lending booms on such countries is insignificant.<sup>25</sup>

43. Since the model does not predict the discrete event of whether a country has a crisis or not, but rather the level of an index of exchange market and reserve pressure, it is not possible to assess how well the model fits the data in terms of a proportion of crises correctly called, as done for the other studies. The STV framework predicts which countries should face the greatest pressure on the crisis index during a period of global financial turbulence such as the Mexico crisis.<sup>26</sup> This suggests evaluating the performance of the model by comparing rankings of countries based on the predicted and actual crisis indices, as shown in Table 3. One would expect the predicted rankings to match up relatively well with the actual rankings, since these are in-sample predictions, that is, predictions for the period that the model was designed to explain. Indeed, the table shows that there is a positive and significant correlation between the actual and predicted crisis indices. However, less than one-quarter of the variation in actual rankings is explained by the predicted rankings.

### **D. Developing Country Studies Division Model**

44. The DCSD model uses monthly data to determine which variables contribute to the probability of a crisis occurring within the following 24 months. The probability of this event is estimated in a probit regression model. This has two advantages: the model can aggregate predictive variables more satisfactorily into a composite probability, taking account of

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<sup>24</sup>Weak banking systems are proxied in a somewhat crude way by the presence of a "lending boom" under the view that rapid expansion of bank assets is associated with a deterioration of the quality of those assets.

<sup>25</sup>The original STV results, with a slightly different sample, are more successful in fitting the 1994/95 crises.

<sup>26</sup>The objective of the original STV exercise was largely to explain, not predict, the incidence of crises. Tornell (1998) and others have used the same framework with a more explicit predictive intent.

Table 3. Correlation of Actual and Predicted Rankings Based on Sachs-Tornell-Velasco (STV) Approach: In-Sample

	Actual		Predicted	
	Crisis Severity	Rank	Crisis Severity	Rank
Mexico	791.32	1	293.57	2
Argentina	202.09	2	322.11	1
Brazil	197.01	3	186.05	4
Uruguay	85.03	4	74.57	7
Philippines	71.87	5	168.08	5
Venezuela	51.65	6	12.89	10
Taiwan Province of China	44.00	7	69.61	8
Colombia	42.29	8	49.25	9
South Africa	22.32	9	-1.50	11
Zimbabwe	15.79	10	-85.30	23
Indonesia	13.15	11	-19.23	17
Sri Lanka	7.37	12	-27.88	19
Pakistan	6.77	13	-35.80	20
India	-12.28	14	-11.48	15
Jordan	-15.64	15	-36.76	21
Thailand	-18.19	16	78.59	6
Turkey	-24.92	17	-16.96	16
Malaysia	-26.24	18	-5.88	13
Peru	-26.86	19	-36.86	22
Korea, Republic of,	-37.01	20	-26.00	18
Chile	-56.17	21	-3.68	12
Bolivia	-63.77	22	241.11	3
Israel	-91.40	23	-10.37	14
Correlation 2/				0.49
P-value				0.018
R <sup>2</sup>				0.24

Source: Staff calculations.

1/ Actual Crisis (November 1994–April 1995).

2/ Spearman Rank correlation of the fitted values and the actual crisis index and its p-value. The R<sup>2</sup> is from a regression of fitted values on actual values.



correlations among different variables; and it is easy to test for the statistical significance of individual variables. In addition, it is possible to allow the risk of a crisis to increase linearly with the predictor variables.<sup>27</sup>

45. The model is obtained by including the fifteen KLR variables (where sufficient data were available) plus three additional variables, then simplifying by dropping insignificant variables.<sup>28</sup> The additional variables are the level of M2/reserves, the current account to GDP ratio and the ratio of short-term debt to reserves. The results indicate that the more significant variables are: the real exchange rate relative to trend, the current account deficit, reserve growth, export growth, and the ratio of short-term debt to reserves.

46. The DCSD model excluding short-term debt performs about as well in-sample as the KLR model, as shown in Table 2. Because the variable is only available from 1986, the model that includes this variable is estimated over a shorter period. The in-sample performance is somewhat worse in this specification than for the model excluding short-term debt. Using a 25 percent cutoff, the model including short-term debt to reserves predicts a crisis 39 percent of the times that it should, while 64 percent of alarms are false.

#### **E. Out of Sample Performance: 1997**

47. For an EWS to be a useful tool, it would have to provide informative signals out of sample, namely, beyond the time period for which the model itself was estimated. An interesting (although by no means complete) test of the out-of-sample performance of the models reviewed here is to check whether they produced signals of impending trouble ahead of the crises of 1997 using only the data available before the crisis. Because the maximum prediction horizon of KLR and DCSD is two years, these models were estimated using only data through April 1995 to forecast crisis probabilities for 1997 and to compare those forecasts with the outcomes. FR was estimated using annual data through 1996, and STV through April 1995 .

48. The out-of-sample performance of the models can be evaluated in two ways. First, a natural assessment of the model performance is to check whether the models predicted high probabilities of crisis (above say, 50 or 25 percent) in the periods preceding actual crises. This goodness-of-fit test evaluates the success in predicting the *timing* of crises. Second, given the rather unpredictable nature of the timing of global turbulence and contagion, the

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<sup>27</sup>The KLR approach, in contrast, assumes that the probability of crisis in the subsequent 24 months is a step function of the value of the indicator, equal to 0 when the indicator variable is below the threshold and equal to 1 at or above the threshold. Berg and Pattillo (1998) found that a probit model with variables entered linearly had somewhat higher predictive power than the pure threshold framework.

<sup>28</sup>See Berg and Pattillo (1998) for a full discussion of the specification and estimation of the DCSD model.

models can be put to the test of predicting the relative severity of crises (or, more precisely, measures of balance of payments pressure) faced by different developing countries. That is, one would judge the success of the models by how they anticipated—again using only previously available information—the relative intensity of balance of payments pressures suffered by different countries. The performance of the models is then assessed by comparing a ranking of countries according to the value of their crisis index as predicted by the models with their ranking using actual data for 1997.

49. The first type of test, evaluating whether the models predicted probabilities of crisis accurately, was applied to the KLR and DCSD models only because it was not possible to produce meaningful goodness-of-fit measures of this kind for the FR and STV models, for different reasons. According to the FR definition, there are no actual crises in 1997, so there are no crises to predict. This odd result illustrates the fact that the use of annual data does not work well for the crisis variable in 1997. Because the largest depreciations happened toward the end of the year, none of the Asian countries is identified as a crisis country in 1997 within this framework.<sup>29</sup> The problem with the STV framework is that it does not predict the timing of discrete crisis events, but rather predicts which countries should face the greatest pressure as measured by a crisis index during a period of global financial turbulence. Thus, this model cannot be subjected to the first test because it is not possible to extract from it a prediction of the probability of crisis, although it is ideally designed for ranking countries by their level of risk, as in the second test.

50. The out-of-sample performance of the KLR model is less successful than the in-sample performance though also more selective as Table 4 shows. With a 25 percent probability cutoff, the KLR-based predicted probabilities correctly signal 34 percent of the crisis observations (as opposed to almost one half within sample), while the incidence of false alarms falls to 51 percent.<sup>30</sup> From the perspective of a decision-maker attempting to interpret the signals coming from the model, the model continues to provide predictions of some value, even out of sample. For observations in which the predicted probability of approaching crisis was below 25 percent, crises actually followed 24 percent of the time. When the predicted probability of crisis was above 25 percent, however, crises ensued 49 percent of the time.

51. The DCSD model performs much better out-of-sample. Again, with the 25 percent cutoff probability it correctly predicts a crisis in 73 percent of the observations that are actually followed by crises. Less than half the time that a crisis was predicted, no crisis ensued within 24 months. The contribution of the model to the analysis of the external risk

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<sup>29</sup>Actually, a few countries came very close to meeting the FR conditions for identification of a crisis, most notably Indonesia and Turkey.

<sup>30</sup>It is remarkable that, applying a probability cutoff of 50 percent, the predictions generated on the basis of the KLR model do not forecast *any* crisis in the whole May 1995- December 1997 period.

Table 4. Predictive Power of Kaminsky-Lizondo-Reinhart and Developing Country Studies Division Models: Out-of-Sample

	KLR Weighted-Sum Based Probabilities	DCSD Probabilities
<b>Goodness-of-Fit: (cut-off probability of 50 percent)</b>		
Percent of observations correctly called	70	74
Percent of pre-crisis periods correctly called 1/	0	3
Percent of tranquil periods correctly called 2/	100	100
False alarms as percent of total alarms 3/	No crisis predictions	0
Probability of crisis given:		
An alarm 5/	0	100
No alarm 6/	29	27
<b>Goodness-of-Fit: (cut-off probability of 25 percent)</b>		
Percent of observations correctly called	70	79
Percent of pre-crisis periods correctly called 1/	34	73
Percent of tranquil periods correctly called 2/	86	81
False alarms as percent of total alarms 3/	51	41
Probability of crisis given:		
An alarm 5/	49	59
No alarm 6/	24	11

Sources: Berg and Pattillo (1998), and staff calculations.

1/ This is the number of pre-crisis periods correctly called (observations for which the estimated probability of crisis is above the cut-off probability and a crisis ensues within 24 months) as a share of total pre-crisis periods.

2/ This is the number of tranquil periods correctly called (observations for which the estimated probability of crisis is below the cut-off probability and no crisis ensues within 24 months) as a share of total tranquil periods.

3/ A false alarm is an observation with an estimated probability of crisis above the cut-off (an alarm) not followed by a crisis within 24 months.

5/ This is the number of pre-crisis periods correctly called as a share of total predicted pre-crisis periods (observations for which the estimated probability of crisis is above the cut-off probability).

6/ This is the number of periods where tranquility is predicted and a crisis actually ensues as a share of total predicted tranquil periods (observations for which the estimated probability of crisis is below the cut-off probability).

faced by the countries can be appreciated in the following way. The predicted probability of crisis was below 25 percent during most of the out-of-sample period under consideration. For these observations, crises actually occurred only 11 percent of the time. When the predicted probability of crisis was above 25 percent, however, crises ensued 59 percent of the time.

52. This good performance is illustrated by examining all the countries which experienced a crisis in 1997. Except for Philippines, the probabilities were above 25 percent for most of the 24 months preceding the first month of the crisis. Looking at countries which did not experience a crisis shows that false alarms were a bigger problem for some countries than others. For Argentina, the probabilities were above 25 percent in only one of the 20 months from May 1995 to December 1996, but in eleven for Peru.

53. The second test focusses on the success of the models in identifying which countries would be vulnerable in a period of global financial turmoil such as 1997. The question here is whether the models assign higher predicted probabilities of crisis to those countries that had the biggest crises (as defined by each model).<sup>31</sup> This can be addressed by comparing how closely the predicted ranking resembles the actual one, as shown in Table 5. An additional benefit of the ranking comparison is that it provides a unified method to evaluate the forecasting performance of all four models. Clearly, a model forecasts successfully if countries that have the highest predicted probabilities of crisis are those that also display the highest values in the severity of crisis index. Thus, the table displays the correlation between the actual and predicted rankings, as well as the proportion of the variance in the actual rankings that is explained by the predicted rankings.

54. The rankings generated from predictions based on the four models are all positively correlated with the actual rankings according to developments in 1997. Yet the correlation is not very high, as it varies from 12 percent to 53 percent. The two models based on monthly indicators (KLR and DCSD) seem to do somewhat better according to this test, as they show higher correlation and statistical significance. Some of the models attach fairly high risk to the Asian economies and Brazil, which also experienced large reserve losses in 1997. It should be noted that the "actual" crisis rankings are based on the definition of crisis applied by each model, and thus are not mutually consistent.

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<sup>31</sup>In the KLR, STV and DCSD models, a crisis is defined to occur when a weighted average of the exchange rate depreciation and loss of reserves exceeds its average by a certain magnitude. FR define a crisis as an exchange rate depreciation of at least 25 percent that also exceeds the previous year's depreciation by at least 10 percent.

Table 5. Correlation of Actual and Predicted Rankings for 1997

	KLR		DCSD	FR		STV	
	Actual Crisis Index	Predicted Probabilities of Crisis 1/	Predicted Probabilities of Crisis 1/	Actual Crisis Index	Predicted Probabilities of Crisis	Actual Crisis Index	Predicted Probabilities of Crisis
Korea	1	4	9			3	11
Thailand	2	7	3	3	11	2	5
Indonesia	3	11	6	2	7	1	9
Malaysia	4	13	4			4	6
Zimbabwe	5	9				5	12
Philippines	6	1	17	7	8	6	1
Taiwan Province of China	7	3	1			9	22
Colombia	8	12	2	8	6	8	4
India	9	21	11	14		13	19
Brazil	10	2	15	10	5	14	2
Turkey	11	10	12	1	2	7	21
Venezuela	12	16	20	5	12	21	13
Pakistan	13	5	5	6	9	10	20
South Africa	14	8	7			12	16
Jordan	15	17	14			17	15
Sri Lanka	16	19	13	11	13	15	17
Chile	17	20	18	15	10	16	14
Bolivia	18	21	22	13		22	10
Argentina	19	18	19	16	3	23	7
Mexico	20	14	21	12		18	18
Peru	21	6	8	9	4	20	23
Uruguay	22	21	16	4	1	11	3
Israel	23	15	10			19	8
Correlation 2/		0.52	0.53		0.12		0.23
P-value		0.011	0.011		0.694		0.295
R <sup>2</sup>		0.28	0.29		0.02		0.05

Sources: Berg and Pattillo (1998), and staff calculations

1/ Average of 1996 estimates of probabilities of crisis in 1997.

2/ Spearman Rank correlation of the fitted values and the actual crisis index and its p-value. The R<sup>2</sup> is from a regression of fitted values on actual values.

## **F. Summary of Effectiveness**

55. This section has examined how well four empirical models work in predicting currency crises. The results indicate that, when an estimated probability of 25 percent or higher is taken as a prediction of a crisis, the best “pure” out-of-sample model correctly predicts roughly one-half of the crises in sample, and one-third out of sample. False alarms are always common: over half the times all these models predict a crisis is approaching, no crisis occurs. Despite the high incidence of false alarms, a prediction of crisis by the model does reflect a situation of increased risk. Periods in which the model calls a crisis are substantially more likely to be followed by a crisis than periods in which the model does not call a crisis, both in sample and—to a lesser extent—out-of-sample.

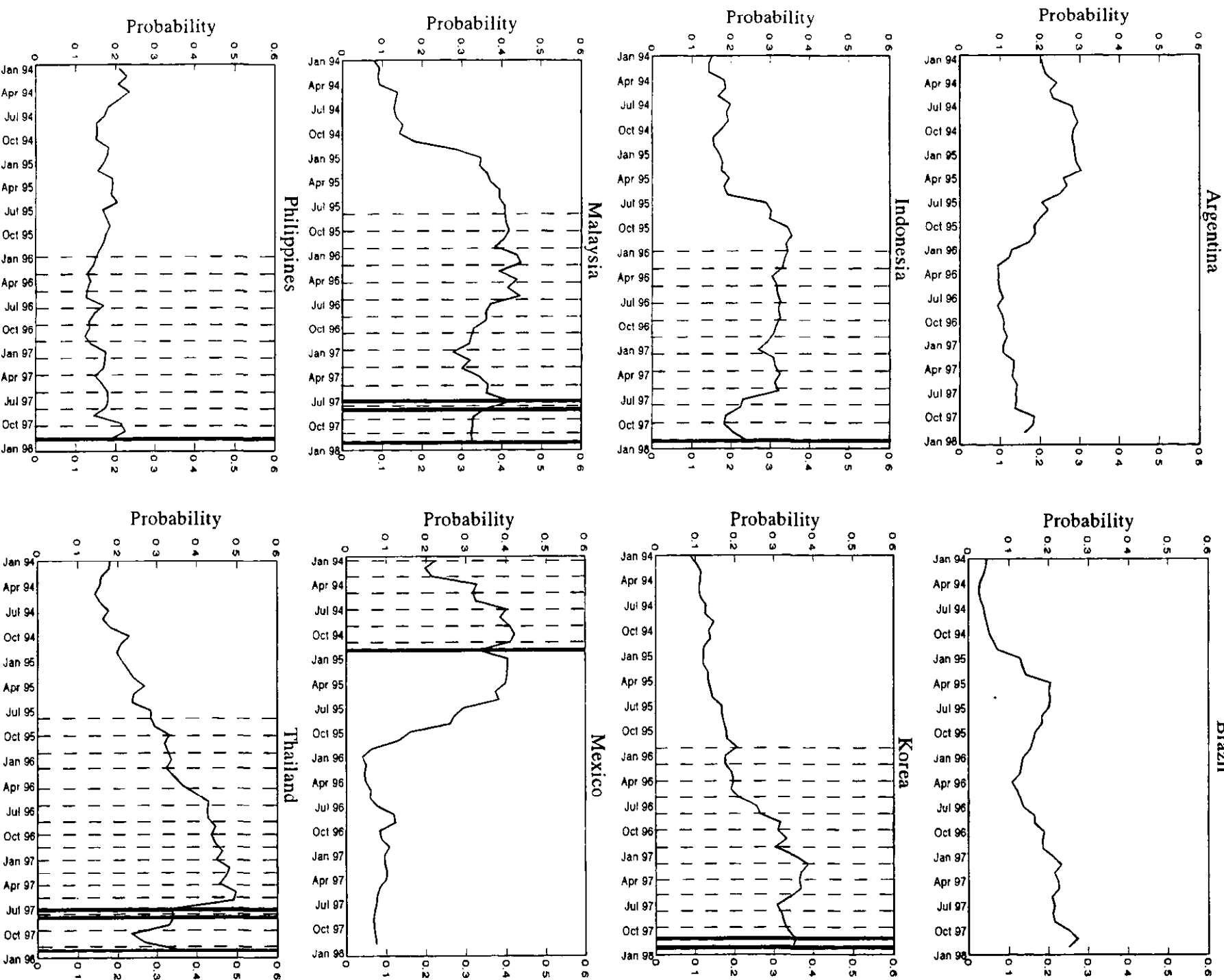
56. The DCSD model performs substantially better out-of-sample. When this model indicates a probability of crisis above 25 percent, a crisis is in fact looming most (59 percent) of the time. And when the predicted probability of crisis is below 25 percent, a crisis in fact ensues only 11 percent of the time. Chart 2 displays the out-of-sample probabilities of crisis based on the DCSD model for a selected group of eight countries, five Asian countries and three Latin American countries. The chart shows a relatively high probability of crisis during the period preceding crises for Korea, Indonesia, Malaysia, and Thailand. The risk of crisis in the Philippines is somewhat lower but still close to the cutoff threshold. Of the Latin American countries, none of which suffered crises in 1998, only Brazil experiences a relatively high probability of crisis during this period.

57. It is perhaps not surprising that the DCSD model, which was formulated after the 1997 crises, performs better than the others out-of-sample. First, some knowledge about the 1997 crises was used to formulate the model. In particular, the inclusion of short-term external debt as a predictive variable was in part inspired by events in 1997. However, this factor should not be exaggerated. Most importantly, out-of-sample performance was not used as a factor in specifying the model. Another reason for the superior performance of the DCSD model is simply that as a latecomer it has benefitted from a number of methodological innovations inspired by the previous models and other research, as described in Berg and Pattillo (1998). Ultimately, only time will tell whether newer models continue to perform well in predicting future crises.

58. While timing seems quite difficult to predict, some of the models do better in predicting the relative severity of crisis for different countries in 1997. This suggests the models may be more useful in identifying which countries are more vulnerable in a period of international financial turmoil than in predicting the timing of currency crises. This would still be a valuable contribution of an EWS because it could help focus attention on the countries that need policy adjustments before a crisis develops. Furthermore, comparing the relative risk faced by different countries, which may be very diverse in geographical and economic terms, is not easy to do without applying systematic quantitative techniques.

59. Independently of the value of the models as precise predictors of crises, the analysis of their findings provides some insight into which variables are the most important

Chart 2. 24-Month Ahead Crisis Probabilities for Selected Countries 1/



Source: IMF staff calculations.

1/ Based on the DCSD model. The solid vertical lines represent crisis dates. The areas with dashed lines denote the 24 months prior to crises.

determinants of crises. All approaches demonstrate that the probability of a currency crisis increases when domestic credit growth is high, the real exchange rate is overvalued relative to trend, and the ratio of M2 to reserves is high. Large current account deficits and reserve losses increase the probability of crisis in all three of the methods that include these variables. High short term debt to reserves ratios are also found to lead to an increased probability of crisis in the specifications that use this variable. Some evidence is also found for the importance of other variables, such as export growth, the size of the government budget deficit, and the share of FDI in external debt. Surprisingly, output growth was not found to be a significant predictor of crises when tested. The evidence on interest rates was mixed. High domestic real interest rates provide informative signals of impending crises while the differential between foreign and domestic real interest rates does not; yet in one specification high foreign interest rates do increase the probability of a currency crash.

## V. THE IMPLEMENTATION OF AN EARLY WARNING SYSTEM

60. The summary of the predictive performance of some representative EWSs indicates some degree of success but more mixed results concerning the reliability of the warning signals that may be issued by any such system. In addition, there are a number of issues that should be considered in connection with the possible implementation of an early warning system in support of Fund surveillance activities. The issues relate to the general applicability of an EWS to Fund surveillance, the specific countries to which such a system may be more usefully applied, the way in which results from an EWS could be used by the Fund, and the level of dissemination of results both within the Fund and more widely.

61. While there has been a recent flurry of research on the prediction of currency crises, it is clear that more work needs to be done to better understand their causes and more successfully predict them. The empirical literature on EWSs is relatively young, at least for models with an explicit forecasting objective, especially when compared with, say, leading indicators of business cycles or large-scale macroeconomic models that have been in development for several decades. Many ideas have not yet been explored satisfactorily, including basic issues such as the empirical definition of a crisis. It may also be possible to incorporate new variables that seem to be relevant but have not previously been available in the desired format or frequency, such as measures of non-performing loans in the banking sector, more refined measures of short-term liabilities (including valuations of the forward and contingent positions of the monetary authorities, for example), and even the budget deficit. An important feature of currency crises that deserves further study is contagion, which is difficult to incorporate in a satisfactory way but which undoubtedly plays a role at least in the timing of crises. Other issues that should be studied include institutional factors such as the strength of regulatory frameworks, corporate governance, the degree of openness of the capital account and variables accounting for political developments. Finally, various aspects of the specification of models could be further studied to improve their reliability, including reconsidering the most appropriate forecast horizon.

62. The work done to date and reviewed in Section IV nonetheless suggests that it might be fruitful to implement—experimentally—a quantitative early warning system. Early



warning systems can produce estimates of the probability of crisis and rankings of the susceptibility to crisis of different countries that contain significant useful information. In particular, Section IV demonstrated that some of the models can forecast with at least a modest degree of success the timing of crises, and that they do better still at predicting the cross-country vulnerability to crisis. That is, they may help predict which country is more likely to suffer a crisis during a given period, even if they do less well at predicting how many crises there will be in that period. Moreover, the implementation of a system would likely lead to the improvement of the EWS as it would allow ongoing testing of the accuracy of forecasts, examining alternative specifications, introducing new variables, and other modifications.

63. How should an early warning system be used? A central fact conditioning the answer to this question is that the accuracy of such a system is likely to be highly imperfect. Section IV showed that while early warning systems help identify patterns common to many crises, they cannot be expected to predict with complete, or even high, accuracy. While further research can be expected to improve performance, many of the reasons for inaccuracy, detailed above, will remain. In particular, the timing of crises may be impossible to forecast as it may depend on changes in market sentiment and other inherently unpredictable events. Moreover, even a system that is highly successful from a statistical point of view would only address part of the relevant information regarding the prospects for a crisis. The analysis of the vulnerability of an economy involves many more aspects than can be summarized in a handful of generally available variables.

64. This suggests that an EWS should be viewed as an additional tool for surveillance rather than as a self-contained forecasting method. By design, EWSs exploit the variability in countries' experiences to extract information about the likelihood of a crisis. This cross-country approach provides a richer basis than studying only a single country, which may have faced a crisis situation only on a few (or even no) occasions during the period under study. Area departments already examine the behavior of various indicators of risk, mostly on a country-by-country basis. An early warning system would provide a more systematic basis for doing so, and perhaps also for interpreting the combined effect of several different indicators for each country. This approach could, therefore, enrich current Fund analysis which tends to be focussed on country-specific information and evaluation; it may also be closer to the analysis of those international investors who rely on a comparison of risk and returns across countries to make investment decisions.

65. It should still be recognized that such an EWS framework presumes that differences in economic structure, institutions, etc. across countries are not so important as to negate the effectiveness of a cross-country approach. However, key determinants of the likelihood of crisis may not be the same across countries, or their relative impact may differ. And the relevant factors may change over time as the level of economic development and market structures change. This suggests the use of a fairly homogeneous group of countries and sample period in the design of an EWS to minimize such problems. For instance, these models are likely to apply better to the group of "emerging" economies that have been more active in international capital markets over the past few years.

66. In view of these considerations, it would seem unwise for the Fund to publish early warning indicators of potential crises, or to run risks that they might become publicly known. First, the accuracy of an EWS is such that many crises would be missed and many false alarms would occur. Second, there would be the risk that issuing a signal could trigger a market panic, that is, produce a crisis when one otherwise would not have occurred. The dangers of wrong signals (either positive or negative) would suggest that the output of an EWS, at least when considered in isolation, should be for internal use, rather than public consumption.

67. Some care should be taken in interpreting false alarms as "mistakes" made by the models. First, the authorities in these countries may have taken policy measures to ward off a looming crisis. More generally, it may be that these false alarms occurred in situations where countries were truly at risk but did not suffer a crisis owing to favorable external developments, or even good luck. As discussed in Appendix I, theoretical models that emphasize self-fulfilling crises imply that, for a range of values of fundamentals, crises may happen but are not inevitable. The best an EWS could do would be to assign higher probabilities of crisis to countries that are more vulnerable to a shift in expectations. This would still be useful information, as the model would essentially generate correct warnings, even though many of these warnings would be counted as false alarms ex post.

68. A regularly updated and analyzed EWS could thus serve as an input to the Fund's internal surveillance work, by providing an additional instrument to judge the balance of payments risks for a cross-section of emerging economies. Three possible uses are envisaged. First, EWS results could form part of an ongoing monitoring of regional or global emerging market conditions, which would be discussed periodically with staff and management, for instance, at Surveillance Committee meetings. Second, predictions of various EWS models could be an input to the periodic presentations to the Executive Board of World Economic and Market Developments (WEMD). Rather than being included at each six-weekly session of the WEMD, however, it would be proposed that updated results be included in the Economic Counselor's oral presentation every six months or so, or if circumstances made them especially relevant. Third, the results from an EWS model could be applied on a case-by-case basis to evaluate the external risks faced by a country, and serve as an input to area department consultations with the authorities.<sup>32</sup>

69. In all three of the proposed uses, it would be necessary of course to examine other variables to decide in each case whether special circumstances outside a particular EWS were also relevant. Rather than relying on a single EWS, Fund staff would endeavor to compare the results of its preferred specification with others developed elsewhere. Moreover, as with other composite indicators (such as leading economic indicators), a better understanding of the implications of a signal can be obtained by also looking at the behavior of the individual

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<sup>32</sup>Results from an EWS have, in fact, already been considered in the evaluation of external risks by some country missions.

indicators making up the composite (in this case, the crisis probability). If all (or most) of them point in the same direction, one may have some confidence in the result, but if not, one may question the reliability of the signal.

70. To conclude, early warning systems should be used but not abused. This means that the primary use of an EWS should be as only one tool among many others for analysis by Fund staff. They cannot substitute for existing Fund surveillance efforts, whether at the level of individual countries or regions or globally through the World Economic Outlook. Thus, any utilization of early warning systems must be embedded in broader analysis that takes into account all the important complexities, some of which a cross-country statistical model inevitably must ignore.

#### **A. Issues for Discussion**

71. Executive Directors may wish to comment both on the usefulness of early warning systems for Fund surveillance and on some aspects of their possible implementation.

- Directors may wish to discuss the advantages and disadvantages of the use of cross-country systematic models to assess the risk of balance of payments crises, relative to more traditional country-based surveillance.
- Directors may wish to discuss the range of variables that may be useful as indicators of impending crises. The review of the EWS model performance in this paper suggested three types of variables: (i) those referring to internal and external macroeconomic balance, including domestic credit growth, real exchange rate overvaluation, the current account deficit, and to a lesser extent, export growth, the size of the government budget deficit, and the share of FDI in external debt; (ii) variables that measure the vulnerability to sudden capital outflows, such as the ratio of M2 to reserves, the ratio of short-term external debt to reserves, and past reserve losses; and (iii) variables that represent market sentiment and contagion, such as the differential between foreign and domestic real interest rates and the number of crises in recent months.
- Do Directors agree that the best target for application of an EWS would be the group of emerging countries with a more active presence in international capital markets?
- Predictions from an EWS give rise to two types of errors: failing to predict a crisis that actually happens and producing a prediction that turns out to be a false alarm. The calibration of the model can be adjusted to make it less likely to generate one type of error or the other. Directors may wish to discuss the tradeoffs they perceive in this respect, i.e., the cost of missing crises relative to false alarms.
- Crises are by their nature uncertain and difficult to predict. Given the dangers of forecasting crises that do not occur, or that may be triggered by the forecast itself, do Directors believe that an early warning system should be for internal use, rather than

lead to public warnings of potential crises? If so, should that internal use be to supplement staff judgements on individual countries, and to provide an input into other surveillance activities, such as the WEO and the WEMD?

## A BRIEF SURVEY OF THE LITERATURE ON CURRENCY CRISES

72. This Appendix provides a selective review of the economic literature on currency crises focussing on the explanations that have been advanced of the determinants and the processes leading to crises.<sup>33</sup>

### First-Generation Models

73. In his seminal paper on balance-of-payments crises, Krugman (1979) considers a small open economy with a pegged exchange rate where domestic credit expands continuously, typically to finance a budget deficit. The peg is sustained by a positive stock of foreign exchange reserves, but reserves are gradually depleted as agents continuously buy foreign currency as a result of the imbalance between the expanding domestic credit and the stable money demand. Krugman shows that reserves will eventually be wiped out by a speculative attack once they have reached a sufficiently low level, even though there is no change in policies to trigger the attack. With well-informed, rational speculators assessing the situation, the currency attack will take place only when the transition from the pegged exchange rate to its successor system (presumed to be a float) yields the required return to speculators. Although the policy inconsistency that condemns the exchange rate system is well recognized in advance, and the eventual demise of the peg is known to be unavoidable, it is not profitable to launch an attack too early (or to wait too long). In fact, the determination of the timing of the attack is the main analytical question that first-generation models attempt to answer.

74. Although Krugman's model is very stylized, and may seem artificial, other models have extended his framework to capture the features usually present in balance of payments crises. With some degree of price sluggishness or the introduction of nontraded goods, the build-up to a crisis features an appreciating real exchange rate and widening current account deficits (Calvo (1987)). Introducing some degree of uncertainty, the timing of the devaluation cannot be exactly predicted and a "peso problem" emerges, that is, a persistent divergence between nominal domestic and foreign interest rates owing to the expectation of an impending devaluation (Krasker (1980), Penati and Pennacchi (1989)).

75. Several empirical studies of devaluations have found common features that are consistent with the framework of first-generation models. Indeed, large devaluations in developing countries have often been preceded by expansionary fiscal and monetary policies, interest-rate premia, real exchange rate appreciations and widening current account imbalances (Edwards (1989)). Analyses of individual country experiences have also found a

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<sup>33</sup>For comprehensive reviews of the theoretical and empirical literature, see Garber and Svensson (1995) and Flood and Marion (1998). Agénor et al. (1992) provide a useful survey of the literature on "first-generation" speculative attacks.

link between excessive credit growth and subsequent crises in a number of case studies of devaluations including in Mexico, Argentina, Italy and France.<sup>34</sup>

## Second-Generation Models

76. The breakdown of the exchange-rate mechanism (ERM) of the European Monetary System in 1993 and the Mexican crisis of 1994 spurred a reconsideration of the explanations of exchange rate crises offered by the economic literature. Some aspects of those crises were hard to reconcile with traditional models of speculative attacks for two reasons. First, as underscored by Obstfeld and Rogoff (1996) among others, the decision to abandon an exchange rate peg in the context of the ERM crises was not due to the exhaustion of foreign exchange reserves, but to the reluctance of governments to fight prolonged speculative attacks with high interest rates. In this regard, the second-generation models explain speculative attacks in a context in which the government decisions take into account the costs and benefits involved in abandoning the peg. In contrast, first-generation models provide no explicit rationale for government policy actions.

77. The second reason for the reassessment of theories of currency crises was the unexpected and apparently inexplicable nature of some of these crises, which led several observers to suggest the possibility that self-fulfilling expectations may have played a prominent role (see Eichengreen and Wyplosz (1993) for an interpretation of the EMS crisis along those lines, and Sachs, Tornell and Velasco (1996) and Cole and Kehoe (1996) for such an interpretation of the Mexican crisis). For example, France was subject to repeated speculative attacks that led to a widening of the fluctuation band vis-à-vis the deutschemark, even though traditional “fundamentals” were not visibly out of line—France had modest fiscal imbalances, its real exchange rate was not appreciated, and it was running a current account surplus.

78. But how can self-fulfilling crises occur? The key feature is the link between the government's assessment of the costs of maintaining the peg and the private sector's expectations. If private investors expect that the peg might be abandoned, the cost to the government of maintaining a fixed exchange rate becomes higher, and this may indeed lead it to devalue the currency, thus validating market expectations. Obstfeld (1994) provides several examples. One is based on the impact of high government debt. When expectations of an impending devaluation are built into nominal interest rates, maintaining the peg will raise the real debt burden significantly. Under the circumstances, the government might find it too costly to keep the exchange rate unchanged. Conversely, if no devaluation is expected the

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<sup>34</sup> See Blanco and Garber (1986) and Goldberg (1994) for Mexico, Connolly (1984) and Cumby and van Wijnbergen (1989) for Argentina, Penati and Pennacchi (1989) for Italy and France.

cost for the government of maintaining the peg is reduced and the peg will be maintained (see also Bensaïd and Jeanne (1997)).<sup>35</sup>

79. It is important to underscore that the possibility that crises can be self-fulfilling does **not** imply that the likelihood of an attack is unrelated to fundamentals. Indeed, in second-generation models, there is typically a range of “strong” fundamentals in which a speculative attack would not occur, that is, the government would never find it advantageous to validate market expectations and devalue the currency. Under these circumstances, it would indeed not be rational for market participants to expect a depreciation. Similarly, there is a range of “weak” fundamentals where the cost of defending the peg (the temptation to devalue) is so high that a speculative attack forcing the abandonment of a peg is inevitable. Finally, there is an intermediate “vulnerable” range of fundamentals, in which a peg could survive if expectations were favorable but would be abandoned if an attack were to materialize (Obstfeld (1996)). A shortcoming of these models is that they do not explain what reasons determine whether the attack takes place or the peg is maintained (see the discussion in Masson (1998)).

80. Second-generation models suggest that crises may be inherently difficult to predict because the currency attacks may or may not materialize rather than being the inevitable and predictable outcome of a progressive deterioration in fundamentals. Yet, while these models and the various country experiences suggest a number of additional indicators of vulnerability to a currency crisis, they do not differ sharply from those suggested by first-generation models. Both kinds of models of speculative attacks have a similar implication: attacks always occur in countries with weak (or “vulnerable”) fundamentals in the macroeconomic sense. In fact, it is usually hard to distinguish whether fundamental policy inconsistencies or self-fulfilling attacks provide the best explanation for a certain episode.<sup>36</sup>

### **The Role of Asset Markets**

81. The models reviewed so far focus squarely on macroeconomic policy. A peg can be abandoned either because of a policy inconsistency or because of a government policy decision that weighs costs and benefits of maintaining the peg. However, some aspects of the Mexican crisis and, especially, the recent crises in several Asian countries seem to be related to market failures in asset markets or distortions in the financial system, rather than resulting from clear macroeconomic imbalances or an exchange rate misalignment. In all of these episodes, investors refused to roll over short-term debt (“tesobonos” in the case of Mexico) and redeemed the proceeds in foreign currency. Authors such as Calvo (1997) have stressed taking a broader view of asset markets rather than focussing exclusively on the evolution of international reserves. For example, if the government is running an unsustainable deficit but

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<sup>35</sup> See Calvo (1988) for an earlier application of this idea to the problem of the persistence of high inflation rates.

<sup>36</sup> See Jeanne (1997) for an attempt to detect the effect of self-fulfilling expectations.

resorts to bond financing rather than monetization of the deficit, international reserves may be stable, rather than declining, in the period leading to an attack. The speculative attack essentially occurs in bond markets, as agents refuse to roll over short-term government paper and convert the proceeds into foreign currency.

82. Although the linkage between financial sector problems and balance-of-payments crises received prominent attention only after Mexico 1994 and, especially, the Asian crisis, it had played an important role in previous episodes (see Diaz-Alejandro (1985) for an insightful discussion). For example, the 1982 crisis in Chile was preceded by a period during which the conduct of fiscal policy was conservative, but the private sector borrowed extensively on international markets. The presence of explicit and implicit government guarantees created a severe moral hazard problem, and external shocks precipitated a crisis that resulted in a costly bailout of the banking system and a "socialization" of private external liabilities. With this experience in mind, Velasco (1987) presents a model of currency and banking crises where a negative external shock reduces the value of banks' assets, but because of the deposit guarantee banks do not liquidate bad loans, relying instead on external borrowing to cover their losses. Once access to external borrowing is curtailed, the government has to intervene and bail out the banks. The costs of the bailout and the 'socialization' of banks' external liabilities leads to a depletion of foreign exchange reserves and a collapse of the peg. More generally, in situations in which the banking system is fragile because of maturity or currency mismatches, crises can occur because the role of the central bank as lender of last resort comes into conflict with the need to defend the exchange rate peg.

83. In the Chilean crisis of 1982, self-fulfilling expectations played no role as the crisis was essentially inevitable given the deposit guarantee scheme and the banks' behavior. In contrast, Goldfajn and Valdés (1996) and Chang and Velasco (1998) highlight the role of banking fragility in making a country more vulnerable to speculative attacks. Bank runs based on self-fulfilling expectations can cause the collapse of a solvent but illiquid domestic banking system, as foreign investors refuse to extend credit or roll over existing loans, in a framework similar to that of the famous banking model of Diamond and Dybvig (1983). Even such purely speculative financial crises can generate large output costs, because banks may be forced to liquidate potentially profitable but illiquid long-term assets to face a liquidity squeeze. A number of factors can make an economy more vulnerable to this type of "run", among them, a large share of short-term external debt and a lowering of reserve requirements. Empirical evidence presented by Kaminsky and Reinhart (1996) shows indeed that banking crises tend to precede balance-of-payments crises.<sup>37</sup>

84. In addition to underlining the importance of asset-market problems, the recent Asian crisis has focused attention on the role of moral hazard generated by implicit government guarantees of private sector external liabilities. In Krugman (1998), government provision of

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<sup>37</sup> See also Demirgüç-Kunt and Detragiache (1998).



(implicit) bailout guarantees leads to private sector overinvestment and asset price inflation.<sup>38</sup> If the bailout guarantee is not unlimited, there will eventually be a collapse in asset prices as the bubble bursts.<sup>39</sup> Corsetti, Pesenti and Roubini (1998) tell a similar story. In their model, the existence of (implicit or explicit) government guarantees leads firms to "overborrow" from abroad. The guarantees, however, are not unlimited. Under these circumstances, it can be shown that a period of overborrowing can be followed by a sudden withdrawal of external funds once doubts surface over the ability or willingness of the government to cover existing losses. These interpretations of crises do not necessarily emphasize self-fulfilling expectations--rather, they rely on the existence of a fundamental distortion that leads to a gradual buildup of imbalances. One interesting aspect is that the contingent nature of these government liabilities implies that fiscal imbalances will emerge ex-post, but may not be detectable ex-ante.<sup>40</sup>

85. Recent experience has also focussed attention on distortions generating large capital inflows and their later reversal. A model by Dooley (1997) postulates that governments provide insurance against external shocks to the private sector, which is thus enticed to borrow at above-market rates.<sup>41</sup> This attracts capital to the country. However, the available resources of foreign exchange reserves for paying "insurance claims" are limited. This implies that the degree of insurance is declining over time, and therefore the rates of interest that the private sector can afford to pay must also be declining, making the reversal of capital flows eventually unavoidable. When foreigners withdraw their funds, the government steps in to bail out the private sector, but in so doing it depletes its foreign exchange reserves and a

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<sup>38</sup>Domestic financial intermediaries will base their decisions on "Panglossian values" for rates of return (i.e, rates of returns that are based only on favorable circumstances, given the government guarantee that would come into effect should circumstances prove unfavorable).

<sup>39</sup> Note that even in this setting in which a crisis is inevitable, self-fulfilling expectations can accelerate the collapse. The reason is that the size of the bailout depends on the magnitude of the fall in asset prices. While government resources may be sufficient to undertake a full bailout for given expectations about asset prices (which would imply no crisis yet) they may be insufficient if asset prices collapse. If agents expect this to occur, they will precipitate a crisis.

<sup>40</sup>It should also be noted that the bursting of an asset price bubble can simply imply that asset prices revert to their "fundamental" values. In contrast, in models emphasizing lack of liquidity, such as Chang and Velasco (1998), potentially viable projects are liquidated and asset prices can fall below their "fundamental" value, emphasizing the importance of providing liquidity.

<sup>41</sup>In other words, the existence of insurance is equivalent to an implicit transfer from the government. Some of the proceeds from this transfer are appropriated by domestic financial intermediaries and the rest by foreign lenders, who earn above-market rates on implicitly guaranteed assets.

crisis occurs. Dooley underlines that if one includes in the government's "war chest" funds made available by international organizations then the moral hazard problem that leads to the capital inflow-crisis sequence is worsened. He also notes that the model provides a simple explanation for contagion: namely, a large bailout by, say, the IMF or the international community may reduce the resources available for similar bailouts in other developing countries.

### **The Role of Contagion**

86. A common feature of all the major financial crises of the 1990s—the EMS, the Mexican peso and its tequila effects, Asian currencies, and the Russian ruble—is the spreading of difficulties from one country to another, commonly referred to as "contagion." In practice, many factors can account for this phenomenon. First, a crisis in one country may be triggered by a large shock common to several countries—for example, an increase in interest rates on world markets—in which case the crisis can be expected to affect other countries particularly vulnerable to this type of shock.<sup>42</sup> Second, devaluation by one country can affect other countries through "spillover effects" (Masson (1998)). These can occur through several channels. For example, countries that either trade intensively with the country in question or compete with it on third markets will experience a loss in competitiveness and a fall in external demand.<sup>43</sup> The recent crises in East Asia and Russia also highlighted the importance of spillover effects that work through the capital account. For example, the Russia crisis affected the profitability and risk appetite of hedge funds, banks and other investors, leading to portfolio adjustments that spread difficulties to other markets.<sup>44</sup> Russia's crisis may have led to a revision in expectations concerning the possibility that the Fund would act as a lender of last resort.

87. Contagion effects proper, in Masson's (1998) taxonomy, occur when crises spread even in the absence of changes in macroeconomic fundamentals. This may occur because of incomplete information and herd behavior on the part of private investors so that a small shock may trigger a massive outflow of capital from several emerging market countries. For example, Calvo and Mendoza (1997) present a model in which investment fund managers choose to "follow the herd" if they are evaluated based on their relative performance vis-à-vis

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<sup>42</sup> Masson (1998) refers to the effects of type of shock as "monsoonal effects".

<sup>43</sup> Gerlach and Smets (1995) provide a theoretical illustration of this channel and an application to Sweden and Finland.

<sup>44</sup> Valdés (1996) highlights how lack of liquidity in one market hit by a crisis may cause contagion by leading financial intermediaries to liquidate positions in other emerging markets.

other managers.<sup>45</sup> This type of “collective action” problem increases the likelihood of large swings in capital flows even in the absence of correspondingly large changes in fundamentals. A crisis can also act as a “wake-up call.” For example, Goldstein (1998) argues that after the Thai crisis investors reassessed the economic and financial situation of other countries in the region and found them to be less creditworthy than previously believed.

88. Empirical work on contagion is still at a preliminary stage. The most basic contagion studies assess whether the existence of speculative attacks elsewhere in the world increase the probability of a currency crisis, controlling for a country’s macroeconomic, financial and external sector factors. Studies use either a simple zero/one variable indicating whether there was a crisis elsewhere in the world, or a measure of the number of recent crises in other countries which gives more weight to the most recent crises (see Eichengreen et al. (1996b) and J.P. Morgan (1997)). There is also some evidence that contagion may have a regional dimension (Kruger et al. (1998)). However, this finding may be due to the fact that countries within a region often have strong trade ties. In fact, some studies suggest that trade linkages are an important factor of contagion: countries that have strong trade links or compete in an export market with a country experiencing a crisis are themselves more likely to have a crisis (see Eichengreen et al. (1996b), Glick and Rose (1998)). For some episodes, however, it seems difficult to argue that trade links were the only, or even an important, channel of transmission (for example, the pressure on Brazil following the collapse of the Russian Ruble in August 1998). Partly for this reason, some analysts have focused on similarities across countries in macroeconomic policies and conditions. However, the hypothesis that contagion spreads more easily to countries with similar macroeconomic fundamentals has not found much empirical support. Testing more directly the importance of financial market spillovers is inherently more difficult, because it would *inter alia* require information on the positions of financial institutions on a global scale.

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<sup>45</sup>Their idea is similar to the one in Scharfstein and Stein (1990), who show that “bad” portfolio managers would mimic the behavior of others so as to “hide in the herd”. Calvo and Mendoza also highlight how investors may react to “rumors” about future returns in a country by shifting their resources out of a country instead of trying to ascertain (at a cost) whether rumors are founded. If emerging market securities represent a small share of their portfolios, investors would choose not to spend resources trying to ascertain whether the “rumor” is accurate.

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