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# Leading Indicators of Currency Crises

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*This paper examines the empirical evidence on currency crises and proposes a specific early warning system. This system involves monitoring the evolution of several indicators that tend to exhibit an unusual behavior in the periods preceding a crisis. When an indicator exceeds a certain threshold value, this is interpreted as a warning “signal” that a currency crisis may take place within the following 24 months. The variables that have the best track record within this approach include exports, deviations of the real exchange rate from trend, the ratio of broad money to gross international reserves, output, and equity prices. [JEL F31, F47]*

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THE COLLAPSE of some Asian currencies in the wake of the floatation of the Thai baht in early July 1997 is the most recent of several episodes in the 1990s rekindling interest in both academic and policy circles in the potential causes and symptoms of currency crises. In particular, the question is whether those symptoms can be detected sufficiently in advance to allow governments to adopt preemptive measures. Accurately forecasting the timing of currency crises is likely to remain an elusive goal for academics and policymakers alike. However, there is clearly a need to develop a warning system that helps monitor whether a country may be slipping into a potential crisis. Financial market participants are interested in this because

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they want to make money, policymakers because they wish to avoid the crisis, and academics because they have a long history of fascination with financial crises.<sup>1</sup> The need for a better monitoring system is all the more apparent in light of the severity of the recent Asian crises.

This paper examines the available evidence on currency crises and proposes an early warning system. To this end, it first reviews briefly the theoretical literature on currency crises. Although excellent surveys are available that provide comprehensive discussions of a number of theoretical issues, this paper focuses on identifying the various indicators suggested by alternative explanations of currency crises. The discussion encompasses papers within the traditional approach, which stress the role played by weak economic fundamentals in inducing a currency crisis, as well as more recent papers, including those that highlight the possibility of self-fulfilling crises.

Second, the paper surveys the empirical literature to take stock of the various approaches used to assess the usefulness of potential indicators of currency crises, and to identify those indicators that have been most reliable. The results indicate that an effective warning system should consider a broad variety of indicators, since currency crises seem to usually be preceded by a broad range of economic problems.

Third, the paper compares the relative merits of alternative approaches in providing early indications of currency crises and, based on this comparison, proposes a specific methodology for the design of an early warning system. While this methodology is novel in the literature on currency crises, it has a long history in the literature concerned with forecasting turning points in the business cycle.

The warning system proposed in the paper—the “signals” approach— involves monitoring the evolution of a number of economic indicators that tend to systematically behave differently prior to a crisis. Every time that an indicator exceeds a certain threshold value, this is interpreted as a warning “signal” that a currency crisis may take place within the next 24 months. The threshold values are calculated so as to strike a balance between the risk of having many false signals (if a signal is issued at the slightest possibility of a crisis) and the risk of missing the crisis altogether (if the signal is issued only when the evidence is overwhelming). Also, since the group of indicators that are issuing signals would be identified, this helps provide information about the source(s) of the problems that underlie a crisis.

The variables that have the best track record in anticipating crises in the context of the “signals” approach include output, exports, deviations of the

<sup>1</sup> See, for instance, Kindelberger (1978).

real exchange rate from trend, equity prices, and the ratio of broad money to gross international reserves. Furthermore, on average, these and other indicators provide signals sufficiently in advance so as to allow for preemptive policy measures. As shown in Kaminsky and Reinhart (1996), knowing that there are banking sector problems is helpful in predicting a currency crash. This latter point is particularly relevant for the Asian currency crises, which have been so closely entwined with the frailty of the domestic financial sector. The evidence does not provide support for some of the other indicators that were considered, including imports, the differential between foreign and domestic real deposit interest rates, the ratio of lending to deposit interest rates, and bank deposits.

## I. The Theoretical Literature

This section summarizes the main explanations for speculative attacks and balance of payments crises that have been presented in the theoretical literature. The aim is to provide some background on why a variety of indicators have been used in empirical work on crises.<sup>2</sup> The theoretical literature on balance of payments crises has flourished following Krugman's seminal paper of 1979. Initially, this literature stressed that crises were caused by weak "economic fundamentals," such as excessively expansionary fiscal and monetary policies, which resulted in a persistent loss of international reserves that ultimately forced the authorities to abandon the parity. More recently, however, some papers have argued that the authorities may decide to abandon the parity for reasons other than a depletion of official international reserves. Instead, they may be concerned about the adverse consequences of policies needed to maintain the parity (such as higher interest rates) on other key economic variables (such as the level of employment).

Recent models also have shown that a crisis may develop without a significant change in the fundamentals. In these models, economic policies are not predetermined but respond to changes in the economy, and economic agents take this relationship into account in forming their expectations. This set of assumptions opens the possibility for multiple equilibria and self-fulfilling crises. These recent theoretical developments accord a smaller role to fundamentals in generating balance of payments crises, but they also have highlighted the importance that other variables may have in helping to predict those crises.

<sup>2</sup>For detailed surveys of the theoretical literature, see Agenor, Bhandari, and Flood (1992), Blackburn and Sola (1993), Garber and Svensson (1994), and Flood and Marion (1995).

## The Traditional Approach

Krugman's (1979) model shows that, under a fixed exchange rate, domestic credit expansion in excess of money demand growth leads to a gradual but persistent loss of international reserves and, ultimately, to a speculative attack on the currency. This attack immediately depletes reserves and forces the authorities to abandon the parity. The process ends with an attack because economic agents understand that the fixed exchange rate regime will ultimately collapse, and that in the absence of an attack they would suffer a capital loss on their holdings of domestic money. This model suggests that the period preceding a currency crisis would be characterized by a gradual but persistent decline in international reserves and a rapid growth of domestic credit relative to the demand for money. Also, to the extent that excessive money creation may result from the need to finance the public sector, fiscal imbalances and credit to the public sector could also serve as indicators of a looming crisis. For that matter, central bank credit to troubled domestic financial institutions would play the same role.

A number of papers have extended Krugman's basic model in various directions.<sup>3</sup> Some of these extensions have shown that speculative attacks would generally be preceded by a real appreciation of the currency and a deterioration of the trade balance. These results have been derived from models in which expansionary fiscal and credit policies lead to higher demand for traded goods (which causes a deterioration of the trade balance) and nontraded goods (which causes an increase in the relative price of these goods, and thus a real appreciation of the currency). They also follow from models in which expectations of a future crisis lead to an increase in nominal wages, which, in the presence of sticky prices, results in higher real wages and lower competitiveness. Also, models that introduce uncertainty about credit policy or about the level of reserve losses that the authorities are willing to sustain to defend the parity show that domestic interest rates would increase as a crisis becomes more likely. Thus, these models suggest that the evolution of the real exchange rate, the trade or current account balance, real wages, and domestic interest rates could be used as leading indicators of crises.

<sup>3</sup>References to these papers can be found in the surveys mentioned above. In addition to those described in the main text, the extensions include post-collapse exchange systems other than a permanent float (such as fixed, crawling, and transitory floats), the possibility of foreign borrowing, capital controls, imperfect asset substitutability, and speculative attacks in which the domestic currency is under buying, rather than selling, pressure.

## Recent Models

While the traditional approach stresses the role played by declining international reserves in triggering the collapse of a fixed exchange rate, some recent models have suggested that the decision to abandon the parity may stem from the authorities' concern about the evolution of other key economic variables—suggesting that yet another family of variables could be useful to predict currency crises.

For instance, Ozkan and Sutherland (1995) present a model in which the authorities' objective function depends positively on certain benefits derived from keeping a fixed nominal exchange rate (such as enhanced credibility in their efforts to reduce inflation) and negatively on the deviations of output from a certain target level. Under a fixed exchange rate, increases in foreign interest rates lead to higher domestic interest rates and lower levels of output, making it more costly for the authorities to maintain the parity. Once foreign interest rates exceed some critical level, the cost of keeping the exchange rate fixed surpasses the benefits, and the authorities abandon the parity. Based on this model, therefore, the evolution of output and domestic and foreign interest rates may be useful as indicators of currency crises.

More generally, this approach suggests that a variety of factors that may affect the authorities' objective function could be used as leading indicators of currency crises. For instance, an increase in domestic interest rates needed to maintain a fixed exchange rate may result in higher financing costs for the government. To the extent that the authorities are concerned about the fiscal consequences of their exchange rate policy, the decision to abandon the parity may depend on the stock of public debt. Also, higher interest rates may weaken the banking system, and the authorities may prefer to devalue rather than incur the cost of a bailout that could result from an explicit or implicit official guarantee on the banking system liabilities.<sup>4</sup> Therefore, the presence of banking problems (say, as reflected in the relative price of bank stocks, the proportion of nonperforming loans, central bank credit to banks, or a large decline in deposits) could also indicate a higher likelihood of a crisis. Leading indicators may also include political variables.

Recent models also have suggested that crises may develop without any noticeable change in economic fundamentals. These models emphasize that the contingent nature of economic policies may give rise to multiple equilibria and generate self-fulfilling crises. A crucial assumption in these models is that economic policies are not predetermined but respond instead to changes in the economy and that economic agents take this relationship into account in forming their expectations. At the same time, the expectations

<sup>4</sup> Velasco (1987) and Calvo (1995) link balance of payments crises to problems in the banking sector.

and actions of economic agents affect some variables to which economic policies respond. This circularity creates the possibility for multiple equilibria and the economy may move from one equilibrium to another without a change in the fundamentals. Thus, the economy may initially be in an equilibrium consistent with a fixed exchange rate, but a sudden worsening of expectations may lead to changes in policies that result in a collapse of the exchange regime, thereby validating agents' expectations.

In Obstfeld (1994), the expectation of a collapse leads to higher wages and lower employment, which prompts the government to abandon the parity out of concern for output. In a second model, expectations of a collapse lead to higher interest rates, prompting the government to abandon the parity out of concern for the increased cost of servicing the public debt. As indicated in Obstfeld (1996), the increase in interest rates could also work through other channels that may affect the government's objective function. For instance, an increase in interest rates may increase the probability of a banking crisis and the associated fiscal costs of a bailout.

An important implication of models with self-fulfilling crises is that predicting crises may be extremely difficult. This type of model suggests that it may be difficult to find a tight relationship between fundamentals and crises, as crises may sometimes take place without a previous significant change in fundamentals. Finally, some recent papers have focused on contagion effects as the spark of a balance of payments crisis. For instance, Gerlach and Smets (1994) present a model in which the devaluation by one country leads its trading partners to devalue in order to avoid a loss of competitiveness.<sup>5</sup> Contagion effects also may arise if investors pay little heed to countries' economic fundamentals, and thus do not discriminate properly among countries.<sup>6</sup> If contagion effects are present, a crisis in a neighboring country may be an indicator of a future domestic crisis.

## II. Indicators and Crises: The Empirical Literature

This section begins with a description of the various methodologies and variables that have been used in the empirical literature to characterize the period preceding currency crises and to assess the probability of such crises. It then proceeds to narrow the list of potential leading indicators to those variables that appear to have worked best, and concludes by highlighting some of the key findings of this literature.

<sup>5</sup> As the authors indicate, the same effect could be derived in a model with multiple equilibria, in which the devaluation by a trade partner worsens expectations about the domestic economy and generates a self-fulfilling speculative attack.

<sup>6</sup> Calvo and Reinhart (1996) and Eichengreen, Rose, and Wyplosz (1996) discuss these and other channels for the transmission of contagion effects.

## Alternative Approaches

Table A1 in the Appendix provides a summary of 28 selected empirical studies on currency crises. The first column lists the study and describes the sample periods and the periodicity of the data, and the second provides information on the countries covered and the type of episode examined. The third column lists the economic and political variables that have been used as indicators; and the last column sketches certain features of the methodology used and the principal goal of the study in question.

These studies provide information on the numerous and varied experiences with currency crises. They examine sample periods that run from the early 1950s to the 1990s, and cover both industrial and developing countries, although with more emphasis on the latter. About half of the studies use monthly data, with the rest using annual or quarterly data or data of varied periodicity. Most of the papers examine the experience of various countries and study several crisis episodes; only a few focus on a single country.

The studies also vary with respect to how a "crisis" is defined. Most of the studies focus exclusively on devaluation episodes. Some of them examine large and infrequent devaluations,<sup>7</sup> while others include in their sample small and frequent devaluations that may not fit the mold of a full-blown currency crisis.<sup>8</sup> A few studies adopt a broader definition of crises. They include, in addition to devaluations, episodes of unsuccessful speculative attacks; that is, attacks that were averted without a devaluation, but at the cost of a large increase in domestic interest rates and/or a sizable loss of international reserves.<sup>9</sup>

The various papers can be grouped into four broad methodological categories. A first group of papers provides only a qualitative discussion of the causes and developments leading to the currency crises. These papers often stress the evolution of one or more indicators, but no formal tests are conducted to evaluate the usefulness of the various indicators in predicting crises.<sup>10</sup>

<sup>7</sup> For instance, Edwards (1989), Edwards and Montiel (1989), Edwards and Santaella (1993), Frankel and Rose (1996), and Milesi-Ferretti and Razin (1998).

<sup>8</sup> For instance, Collins (1995), Flood and Marion (1995), Kamin (1988), and Klein and Marion (1994).

<sup>9</sup> This group includes Eichengreen, Rose, and Wyplosz (1995), Kaminsky and Reinhart (1996), and Sachs, Tornell, and Velasco (1996).

<sup>10</sup> For instance, Dornbusch, Goldfajn, and Valdés (1995) stress an overvalued exchange rate; Goldstein (1996) emphasizes a boom in bank lending; Krugman (1996) focuses on the high debt levels; and Milesi-Ferretti and Razin (1996) highlight the role of servicing costs (adjusted for growth and changes in the real exchange rate).



A second group of papers examines the stylized facts of the period leading up to and immediately following the currency crisis. Sometimes the pre-crisis behavior of a variable is compared to its behavior during “tranquil” or noncrisis periods for the same group of countries.<sup>11</sup> In other instances, the control group is composed of countries in which no crisis occurred.<sup>12</sup> Parametric and nonparametric tests are used to assess whether there are systematic differences between the precrisis episodes and the control group. These tests can be useful in narrowing the list of potential indicators, as not all the variables included in the analysis ended up showing “abnormal” behavior in advance of crises.

A third group of papers estimate the probability of devaluation one or several periods ahead, usually on the basis of an explicit theoretical model, along the lines pioneered by Blanco and Garber (1986) in their discussion of the Mexican crisis of the early 1980s. These papers include individual country studies and multicountry panel studies.<sup>13</sup> Some of these papers also have attempted to shed light on the variables that determine the size of the devaluation.<sup>14</sup> In a related spirit, Sachs, Tornell, and Velasco (1996) seek to identify those macroeconomic variables that can help explain which countries were vulnerable to “contagion effects” following the Mexican crisis of December 1994. The results from this group of studies also help to narrow the list of useful indicators, as some of the variables included turned out to be statistically insignificant in the logit (or probit) estimation exercises typically undertaken.

A fourth type of methodology is used in Kaminsky and Reinhart (1996). This paper presents a nonparametric approach to evaluating the usefulness of several variables in signaling an impending crisis. It can be interpreted as an extension of the methodology that compares the behavior of variables in periods preceding crises with that in a control group. This approach involves monitoring the evolution of a number of economic variables whose behavior usually departs from “normal” in the period preceding a currency crisis. Deviations of these variables from their “normal” levels beyond a certain threshold value are taken as warning “signals” of a cur-

<sup>11</sup> For example, Eichengreen, Rose, and Wyplosz (1995), Frankel and Rose (1996), and Moreno (1995).

<sup>12</sup> See, for instance, Edwards (1989), Edwards and Santaella (1993), and Kamin (1988).

<sup>13</sup> Individual countries are discussed in Cumby and van Wijnbergen (1989), Kaminsky and Leiderman (1998), and Ötoker and Pazarbaşıoğlu (1994 and 1996), among others. Multicountry studies include Collins (1995), Edin and Vredin (1993), Edwards (1989), Eichengreen, Rose, and Wyplosz (1995), Frankel and Rose (1996), Klein and Marion (1994), and Milesi-Ferretti and Razin (1998).

<sup>14</sup> For instance, Bilson (1979), Edin and Vredin (1993), and Flood and Marion (1995).

rency crisis within a specified period of time. Based on the track record of the various indicators, it is possible to assess their individual and combined ability to predict crises. This approach is explained in detail in Section III.

## Indicators

The studies reviewed in this paper used a large variety of indicators. Table A2 in the Appendix presents a list of the 105 indicators used, grouped into six broad categories and some subcategories,<sup>15</sup> including (1) the external sector; (2) the financial sector; (3) the real sector; (4) the public finances; (5) institutional and structural variables; (6) political variables; and (7) "contagion effects." The indicators of the external sector were, in turn, classified into those related to the capital account, the external debt profile, the current account, and international (or foreign) variables. The indicators of the financial sector were split into those that could be associated with financial liberalization, and other indicators.

It is important to note that many of the indicators listed in Table A2 are transformations of the same variable. For instance, several variables are expressed alternatively in levels or in rates of change; sometimes on their own and other times relative to some standard (such as the same variable in a trading partner). For instance, the real exchange rate is expressed, alternatively, on a bilateral basis or in real effective terms; sometimes in levels and other times as deviations from purchasing power parity, a time trend, or its historical average. The use of scale factors also varies across studies. For example, alternative scale factors used for international reserves include GDP, base money, M1, M2, and the level of imports.

After consolidating the different transformations of the same variable, the main indicators used in empirical work, classified by category, are as follows:

- *Capital account*: international reserves, capital flows, short-term capital flows, foreign direct investment, and differential between domestic and foreign interest rates.
- *Debt profile*: public foreign debt, total foreign debt, short-term debt, share of debt classified by type of creditor and by interest structure, debt service, and foreign aid.
- *Current account*: real exchange rate, current account balance, trade balance, exports, imports, terms of trade, price of exports, savings, and investment.

<sup>15</sup> Although the proper classification for most indicators is unambiguous, that of other indicators is to some extent arbitrary as they could have been properly classified in more than one category.

- *International variables*: foreign real GDP growth, interest rates, and price level.
- *Financial liberalization*: credit growth, change in the money multiplier, real interest rates, and spread between bank lending and deposit interest rates.
- *Other financial variables*: central bank credit to the banking system, gap between money demand and supply, money growth, bond yields, domestic inflation, “shadow” exchange rate, parallel market exchange rate premium, central exchange rate parity, position of the exchange rate within the official band, and M2/international reserves.
- *Real sector*: real GDP growth, output, output gap, employment/unemployment, wages, and changes in stock prices.
- *Fiscal variables*: fiscal deficit, government consumption, and credit to the public sector.
- *Institutional/structural factors*: openness, trade concentration, dummies for multiple exchange rates, exchange controls, duration of the fixed exchange rate periods, financial liberalization, banking crises, past foreign exchange market crises, and past foreign exchange market events.<sup>16</sup>
- *Political variables*: dummies for elections, incumbent electoral victory or loss, change of government, legal executive transfer, illegal executive transfer, left-wing government, and new finance minister; also, degree of political instability (qualitative variable based on judgment).

### What Worked Best?

This subsection describes the criteria used to identify those indicators that have proven to be most useful in predicting crises. The idea is to select the indicators whose contribution to the prediction of crises was found to be statistically significant, based on the results presented in the original papers. This necessarily excludes from consideration those variables that were used only in papers that provide a qualitative rather than a formal quantitative assessment of indicators. Therefore, the discussion that follows focuses on papers where (1) the indicators were used to estimate the probability of a crisis; or (2) the indicators’ precrisis behavior was systematically compared with its behavior in a control group (comprising either the same countries during “tranquil” times or noncrisis countries);

<sup>16</sup> Foreign exchange market “events” include significant changes in exchange arrangements (such as devaluations, revaluations, decisions to float, and widening of exchange rate bands). “Crises” overlap with events, but include unsuccessful speculative attacks and exclude changes in exchange arrangements not associated with exchange market pressures.

or (3) the indicators' ability for signaling future crises was systematically assessed in quantitative terms. Also, the discussion focuses primarily on papers that examine the experience of various countries, as their findings are more likely to be suitable for generalization than the findings of papers that study a single experience.

Appendix Table A3 identifies the indicators that worked best by any of the above criteria in the subset of 17 papers that comply with the criteria mentioned above. For those papers that perform the precrisis/control-group comparison, the second column of the table lists those variables for which the difference in behavior was significant (at the 10 percent level or higher) in at least one of the tests performed in the paper. Notice, however, that abnormal behavior in the precrisis period is a necessary but not a sufficient condition for an indicator to be useful, as some of the variables that pass the univariate tests are not significant in multivariate regressions.

For the papers that estimate the one-period- (or several periods) ahead probability of a crisis, the first column of Table A3 shows the variables that were statistically significant (at the 10 percent level or higher) in the logit or probit regressions. This winnows the list of indicators considerably. For instance, Frankel and Rose (1996) initially considered 16 possible indicators, but only 7 of them turned out to be statistically significant. The results presented in Ötoker and Pazarbaşıoğlu (1994) show considerable cross-country variation regarding the variables that survived this test.

In the case of the variables used in Kaminsky and Reinhart (1996), the first column in Table A3 lists those whose behavior in the period leading up to a crisis was significantly different from their behavior during "tranquil" periods. Within this approach, these are the variables that would be expected to issue a relatively large number of good signals (signals that are followed by a crisis) and few false signals (signals that are not followed by a crisis). The criterion was to include in Table A3 those variables that had an (adjusted) noise-to-signal ratio lower than unity.<sup>17</sup> The (adjusted) noise-to-signal ratios for these variables are presented in Table 1 in Section III, where the "signals" approach is explained in detail.

### Some General Results

Table A4 shows the various indicators (after consolidating the different transformations of the same variable) included in these studies. For each indicator, Table A4 shows the number of studies that tested the significance

<sup>17</sup> The calculation of this ratio is described in detail below. Essentially, it is the ratio of false signals (noise) to good signals, adjusted to take into account that in the sample used in the paper the number of opportunities for false and for good signals differ.

of the indicator, as well as the number of studies in which the indicator was found to be significant in *at least one* of the tests conducted.

The comparison of results across the various papers considered above does not provide a clear-cut answer concerning the usefulness of each of the potential indicators of currency crisis. This is not surprising given the number of relevant factors that differ significantly among those papers, such as the set of variables simultaneously included in the tests, the way of measuring those variables, the periodicity of the data, and the estimation technique. Also, as noted above, some variables that are significant in univariate tests are not significant in multivariate tests.

Despite these difficulties, a number of conclusions can be derived from the tally shown in Table A4. The first general conclusion is that *an effective warning system should consider a broad variety of indicators*; currency crises seem to be usually preceded by multiple economic, and sometimes political, problems. The evidence reviewed here points to the presence of both domestic and external imbalances, which span both the real side of the economy and the domestic financial sector.

Second, those individual variables that receive ample support as *useful indicators of currency crises include international reserves, the real exchange rate, credit growth, credit to the public sector, and domestic inflation*. The results also provide support for the trade balance, export performance, money growth, M2/international reserves, real GDP growth, and the fiscal deficit.

Third, *only tentative conclusions can be drawn regarding the other indicators*, primarily because they have been included in only one or two of the studies under review. Subject to this caveat, the results suggest that several foreign, political, institutional, and financial variables (other than those mentioned above) also have some predictive power in anticipating currency crises. Banking sector problems stand out in this regard, an issue that is taken up in the following sections. In addition, Eichengreen, Rose, and Wyplosz (1996) present evidence that a crisis elsewhere, even after controlling for the fundamentals, has predictive power in explaining currency crises.

Fourth, *the variables associated with the external debt profile did not fare well*. Also, contrary to expectations, *the current account balance did not receive much support as a useful indicator of crises*. This may be because the information provided by the behavior of the current account balance to some extent may already have been reflected in the evolution of the real exchange rate. In most of the studies in which the effect of the current account balance was found to be nonsignificant, the real exchange also was included in the test, and had a significant effect.

The issue of the empirical relevance of self-fulfilling crises is subject to debate. A number of findings in Eichengreen, Rose, and Wyplosz (1995)

have been interpreted as evidence of the existence of self-fulfilling crises. Those findings include: (1) many crises did not seem to be linked to the driving forces emphasized by models in the traditional approach; (2) some crises were not preceded, and were not followed, by a weakening of policies, so it is not possible to argue that those crises were produced by economic agents correctly anticipating a future deterioration in policies; and (3) those crises that occurred without obvious causes and were usually not anticipated by the market and not reflected in advance in interest rate differentials.

Krugman (1996) has argued, however, that the findings described in (1), (2), and (3) above do not constitute evidence in favor of self-fulfilling crises. The argument is as follows. Point (1) is evidence against models in the traditional approach and in favor of recent models in which the authorities devalue because of concern for variables other than international reserves, but it is not evidence in favor of self-fulfilling crises. Point (2) provides evidence *against* models with self-fulfilling crises because it is precisely in those models that policies are assumed to respond to private sector actions, including the attack on the currency. Finally, point (3) is not necessarily evidence in favor of self-fulfilling crises because the market should anticipate the possibility of crises (the results summarized here do not support this view), even those of the self-fulfilling type. It would be more reasonable to interpret the evidence in (3) as reflecting some myopia on the part of investors.<sup>18</sup>

Fifth, *market variables*, such as exchange rate expectations (Goldfajn and Valdés, 1998) and interest rate differentials (Kaminsky and Reinhart, 1996), *do not do well in predicting currency crises*, whether these were preceded or followed by deteriorating economic fundamentals or not. This calls into question the assumption embedded in most of the theoretical models, whether these are of the first or second generation variety—namely, that rational agents know the “true” model and embed that into their expectations.

### III. Methodological Issues

This section discusses the relative merits of the alternative approaches used to assess the probability of a currency crisis, and proceeds to describe in some detail a methodology that serves as the basis for the warning system proposed in this paper.

<sup>18</sup> Jeanne (1997) takes a different approach to test for the existence of self-fulfilling crises using data on the French franc/deutsche mark exchange rate for the period 1992–93, and concludes that in fact the estimated relationship has the shape needed to produce multiple equilibria and self-fulfilling crises. These findings, however, are not entirely persuasive, mainly because of the way in which the fundamentals are treated in the estimation.

## An Evaluation of Alternative Approaches

The studies reviewed above have used essentially two alternative methodologies that could serve as the basis for an early warning system of currency crises. The most commonly used approach has been to estimate the one-step- (or  $k$ -step-) ahead probability of devaluation in the context of a multivariate logit or probit model. While the explanatory variables have been rather varied, the estimation technique has been quite uniform.<sup>19</sup> The second approach has been to compare the behavior of selected variables in the period preceding crises with their behavior in a control group, and to identify those variables whose distinctive behavior could be used to help assess the likelihood of a crisis. The particular variant of this approach presented in Kaminsky and Reinhart (1996) has progressed to construct a warning system based on signals issued by those selected variables.

The methodology that estimates the one-step- (or  $k$ -step-) ahead probability of devaluation has the advantage of summarizing information about the likelihood of a crisis in one useful number, the probability of devaluation. Also, this approach considers all the variables simultaneously, and disregards those variables that do not contribute information that is independent from that provided by other variables already included in the analysis.

This methodology does, however, have some important limitations. First, it does not provide a metric for ranking the indicators according to their ability to accurately predict crises and avoid false signals, since a variable either enters the regression significantly or it does not. While measures of statistical significance can help pinpoint which are the more reliable indicators, they provide no information on whether the relative strength of that indicator lies in accurately calling a high proportion of crises at the expense of sending numerous false alarms, or instead missing a large share of crises but seldom sending false alarms. Furthermore, the nonlinear nature of these models makes it difficult to assess the marginal contribution of an indicator at a point in time to the probability of a crisis.<sup>20</sup>

Second, this method does not provide a transparent reading of where and how widespread the macroeconomic problems are. Within this approach, it is difficult to judge which of the variables is "out of line," making it less than ideally suited for the purpose of surveillance and preemptive action.

In contrast, the approach in Kaminsky and Reinhart (1996) tallies the performance of individual indicators, and thus provides information on the

<sup>19</sup> Sachs, Tornell, and Velasco (1996) use an alternative strategy, but they examine the different, although related, issues of which countries were vulnerable on the wake of the Mexican crisis and what accounted for their vulnerability.

<sup>20</sup> Note that this marginal contribution is not independent of the other explanatory variables in the regression.

source and breadth of the problems that underline the probability of a crisis. Furthermore, as explained below, within this approach it is also possible to estimate the probability of a crisis conditional on the signals issued by the various indicators. This conditional probability of crisis will depend directly on the reliability of the indicators that are sending the signals. For instance, if at any point in time six indicators are sending signals, the probability of a crisis conditional on those signals will be higher if the signals are coming from the six best indicators than if they are coming from a less reliable group of indicators.

Based on these considerations, the signals approach seems to be better suited to serve as the basis for the design of an early warning system. The methodology employed, while not previously applied to analyze currency crises, has a long history in the literature that evaluates the ability of macroeconomic and financial time series to predict business cycle turning points. This methodology is described in detail below.

### “Signals” Approach

This subsection describes the “signals” approach as well as some of the empirical results obtained by using this approach. It summarizes the discussion in Kaminsky and Reinhart (1996), who examine 76 currency crises from a sample of 15 developing and 5 industrial countries during 1970–95. It also expands the analysis presented in that paper by ranking the indicators by three alternative metrics: calculating the probability of a crisis conditional on a signal from that indicator; the average number of months prior to the crisis in which the first signal is issued; and the persistence of signals ahead of crises.

#### *Definitions*

As mentioned above, this approach involves monitoring the evolution of a number of economic variables. When one of these variables deviates from its “normal” level beyond a certain “threshold” value, this is taken as a warning signal about a possible currency crisis within a specified period of time. However, to make the approach operational, a number of terms must be defined.

*Crisis:* A crisis is defined as a situation in which an attack on the currency leads to a sharp depreciation of the currency, a large decline in international reserves, or a combination of the two. A crisis so defined includes both successful and unsuccessful attacks on the currency. The definition is also comprehensive enough to include not only currency attacks under a fixed exchange rate but also attacks under other exchange rate regimes. For example, an attack could force a large devaluation beyond the established rules of a prevailing crawling-peg regime or exchange rate band.



For each country, crises are identified (ex post) by the behavior of an *index of "exchange market pressure."* This index is a weighted average of monthly percentage changes in the exchange rate (defined as units of domestic currency per U.S. dollar or per deutsche mark, depending on which is relevant) and (the negative of) monthly percentage changes in gross international reserves (measured in U.S. dollars).<sup>21</sup> The weights are chosen so that the two components of the index have the same conditional variance. As the index increases with a depreciation of the currency and with a loss of international reserves, an increase in the index reflects stronger selling pressure on the domestic currency.

In the empirical application, a crisis is identified by the behavior of the exchange market pressure index. Periods in which the index is above its mean by more than three standard deviations are defined as crises.<sup>22</sup> The appropriateness of this operational definition was checked by examining developments in foreign exchange markets during the periods identified as crises. In many cases, these periods included also other signs of turbulence such as the introduction of exchange controls, the closing of the exchange markets, or a change in the exchange rate regime.

*Indicators:* The choice of indicators was dictated by theoretical considerations and by the availability of information on a monthly basis. They are (1) international reserves (in U.S. dollars); (2) imports (in U.S. dollars); (3) exports (in U.S. dollars); (4) the terms of trade (defined as the unit value of exports over the unit value of imports); (5) deviations of the real exchange rate from trend (in percentage terms);<sup>23</sup> (6) the differential between

<sup>21</sup> Eichengreen, Rose, and Wyplosz (1995) also include the level of domestic interest rates in their index of exchange market pressure, because the authorities could also resort to increases in interest rates to defend the currency. However, this variable was not included in the index used in Kaminsky and Reinhart (1996) because the data on market-determined interest rates in developing countries do not span the entire sample period.

<sup>22</sup> For countries in the sample that, at different times, experienced very high inflation, the criterion for identifying crises was modified. If a single level of the index had been used to identify crises in these countries, sizable devaluations and reserve losses in the more moderate inflation periods would not be identified as crises because the historic mean and variance would be distorted by the high-inflation episodes. To avoid this problem, the sample was divided according to whether inflation in the previous six months was higher than 150 percent, and a different level of the index (based on a different mean and variance) was used to identify crises in each subsample. While this method is admittedly arbitrary, the cataloging of crises obtained by this method follows closely the chronology of currency market disruptions described in numerous articles.

<sup>23</sup> The real exchange rate is defined on a bilateral basis with respect to the deutsche mark for the European countries in the sample, and with respect to the U.S. dollar for all the other countries. The real exchange rate index is defined such that *an increase* in the index denotes a real *depreciation*.

foreign (U.S. or German) and domestic real interest rates on deposits (monthly rates, deflated using consumer prices and measured in percentage points); (7) “excess” real M1 balances;<sup>24</sup> (8) the money multiplier (of M2); (9) the ratio of domestic credit to GDP; (10) the real interest rate on deposits (monthly rates, deflated using consumer prices and measured in percentage points); (11) the ratio of (nominal) lending to deposit interest rates;<sup>25</sup> (12) the stock of commercial banks deposits (in nominal terms); (13) the ratio of broad money (converted into foreign currency) to gross international reserves; (14) an index of output; and (15) an index of equity prices (measured in U.S. dollars).

For all these variables (with the exception of the deviation of the real exchange rate from trend, the “excess” of real M1 balances, and the three variables based on interest rates), the indicator on a given month was defined as the percentage change in the level of the variable with respect to its level a year earlier. Filtering the data by using the 12-month percentage change ensures that the units are comparable across countries and that the transformed variables are stationary, with well-defined moments, and free from seasonal effects.

*Signaling horizon:* This is the period within which the indicators would be expected to have an ability for anticipating crises. This period was defined a priori as 24 months. Thus, a signal that is followed by a crisis within 24 months is called a *good signal*, while a signal not followed by a crisis within that interval of time is called a *false signal, or noise*.

*Signals and thresholds:* An indicator is said to issue a signal whenever it departs from its mean beyond a given threshold level. Threshold levels are chosen so as to strike a balance between the risks of having many false signals (which would happen if a signal is issued at the slightest possibility of a crisis) and the risk of missing many crises (which would happen if the signal is issued only when the evidence is overwhelming).

For each of the indicators, the following procedure was used to obtain the “optimal” set of country-specific thresholds that were employed in the empirical application. Thresholds were defined in relation to percentiles of the distribution of observations of the indicator. For example, a possible set of country-specific thresholds for the rate of growth of imports would be the set of rates of growth (one per country) that would leave 10 percent of

<sup>24</sup> Defined as the percentage difference between actual M1 in real terms and an estimated demand for M1; the latter is assumed to be a function of real GDP, domestic inflation, and a time trend.

<sup>25</sup> This definition of the spread between lending and deposit rates is preferable to using the difference between (nominal) lending and deposit rates, because this difference is affected by inflation and thus the measure would be distorted in the periods of high inflation. An alternative would have been to use the difference between *real* lending and deposit rates.

the observations (on the rate of growth of imports) above the threshold for each country. Notice that while the percentile used as reference (10 percent) is uniform across countries, the corresponding country-specific thresholds (the rates of growth of imports associated with that 10 percent) would most likely differ. This procedure was repeated using a grid of reference percentiles between 10 percent and 20 percent, and the “optimal” set of thresholds was defined as the one that minimized the noise-to-signal ratio; that is, the ratio of false signals to good signals.<sup>26</sup>

## Empirical Results

The effectiveness of the signals approach can be examined at the level of individual indicators (the extent to which a given indicator is useful in anticipating crises) and at the level of a set of indicators (the extent to which a given group of indicators taken together is useful in anticipating crises). The discussion below examines the effectiveness of individual indicators. It extends some of the analysis presented in Kaminsky and Reinhart (1996) by ranking the various indicators according to their forecasting ability, and by examining the lead time and persistence of their signals. An important area for future work would be to combine the information on the various indicators to estimate the probability of a crisis conditional on simultaneous signals from any set of indicators.

In order to examine the effectiveness of individual indicators, it would be useful to consider the performance of each indicator in terms of the following matrix.

	Crisis (within 24 months)	No crisis (within 24 months)
Signal was issued	A	B
No signal was issued	C	D

In this matrix, A is the number of months in which the indicator issued a good signal, B is the number of months in which the indicator issued a bad signal or “noise,” C is the number of months in which the indicator failed to issue a signal (which would have been a good signal), and D is the number of months in which the indicator refrained from issuing a signal (which

<sup>26</sup> For variables such as international reserves, exports, the terms of trade, deviations of the real exchange rate from trend, commercial bank deposits, output, and the stock market index, for which a decline in the indicator increases the probability of a crisis, the threshold is below the mean of the indicator. For the other variables, the threshold is above the mean of the indicator.

would have been a bad signal). A perfect indicator would only produce observations that belong to the north-west and south-east cells of this matrix. It would issue a signal in every month that is to be followed by a crisis (within the next 24 months), so that  $A > 0$  and  $C = 0$ , and it would refrain from issuing a signal in every month that is not to be followed by a crisis (within the next 24 months), so that  $B = 0$  and  $D > 0$ . Of course, in practice, none of the indicators fit the profile of a perfect indicator. However, the matrix above will be a useful reference to assess how close or how far is each indicator from that profile.

Information on the performance of individual indicators is presented in Table 1. For each indicator, the first column shows the number of crises for which data on the indicator are available. The number of crises range from 33 to 72, with an average of 61 crises per indicator. The second column shows the percentage of crises correctly called, defined as the number of crises for which the indicator issued at least one signal in the previous 24 months (expressed as a percentage of the total number of crises for which data on the indicator are available). Virtually every indicator called correctly at least half of the crises in their respective samples. On average, the various indicators called correctly 70 percent of the crises.

The third column of Table 1 shows an alternative measure of the tendency of individual indicators to issue good signals. It shows the number of good signals issued by the indicator, expressed as a percentage of the number of months in which good signals could have been issued ( $A/(A+C)$  in terms of the above matrix). While obtaining 100 percent in the second column of Table 1 would require that at least one signal be issued within the 24 months prior to each crisis, a 100 percent in the third column would require that a signal be issued every month during the 24 months prior to each crisis. In terms of the results in the third column, the real exchange rate is the indicator that issued the highest percentage of possible good signals (25 percent), while imports issued the lowest percentage of possible good signals (9 percent).

The fourth column of Table 1 measures the performance of individual indicators regarding sending bad signals. It shows the number of bad signals issued by the indicator, expressed as a percentage of the number of months in which bad signals could have been issued ( $B/(B+D)$  in terms of the above matrix). Other things equal, the lower the number in this column is, the better the indicator. The real exchange rate, once again, shows the best performance (issuing only 5 percent of possible bad signals), while the ratio of lending to deposit interest rate shows the poorest performance (issuing 22 percent of possible bad signals).

The information about the indicators' ability to issue good signals and to avoid bad signals can be combined into a measure of the "noisiness" of the indicators. The fifth column of Table 1 shows the "adjusted" noise-to-signal

Table 1. *Performance of Indicators Under the "Signals" Approach*

	Number of crises for which there are data (1)	Percentage of crises called <sup>a</sup> (2)	Good signals as percentage of possible good signals (3)	Bad signals as percentage of possible bad signals (4)	Noise/ signal (adjusted) <sup>b</sup> (5)	P(crisis/ signal) <sup>c</sup> (6)	P(crisis/ signal) -P(crisis) <sup>d</sup> (7)
In terms of the matrix in the text			A/(A+C)	B/(B+D)	$[B/(B+D)] / [A/(A+C)]$	A/(A+B)	
Real exchange rate	72	57	25	5	0.19	67	39
Banking crises	26	37	19	6	0.34	46	17
Exports	72	85	17	7	0.42	49	20
Stock prices	53	64	17	8	0.47	49	18
M2/international reserves	70	80	21	10	0.48	46	17
Output	57	77	16	8	0.52	49	16
"Excess" M1 balances	66	61	16	8	0.52	43	15
International reserves	72	75	22	12	0.55	41	13
M2 multiplier	70	73	20	12	0.61	40	11
Domestic credit/GDP	62	56	14	9	0.62	39	11
Real interest rate	44	89	15	11	0.77	34	6
Terms of trade	58	79	19	15	0.77	36	6
Real interest differential	42	86	11	11	0.99	29	0
Imports	71	54	9	11	1.16	26	-3
Bank deposits	69	49	16	19	1.20	25	-4
Lending rate/deposit rate	33	67	13	22	1.69	18	-9

<sup>a</sup>Percentage of crises in which the indicator issued at least one signal in the previous 24 months, out of the total number of crises for which data are available.

<sup>b</sup>Ratio of false signals (measured as a proportion of months in which false signals could have been issued) to good signals (measured as a proportion of months in which good signals could have been issued).

<sup>c</sup>Percentage of the signals issued by the indicator that were followed by at least one crisis within the subsequent 24 months.

<sup>d</sup>P(crisis) is the unconditional probability of a crisis,  $(A+C)/(A+B+C+D)$  in terms of the matrix in the text. This probability ranges from 27 percent to 33 percent depending on the indicator. The unconditional probability varies across indicators because not all of them have observations for the same period.

ratio; this ratio is obtained by dividing false signals measured as a proportion of months in which false signals could have been issued, by good signals measured as a proportion of months in which good signals could have been issued ( $[B/(B+D)]/[A/(A+C)]$  in terms of the above matrix). Other things constant, the lower the number in this column, the better the indicator.

The various indicators differ significantly with respect to their adjusted noise-to-signal ratios. While this ratio is only 0.19 for the real exchange rate (followed by banking crises at 0.34), it is 1.69 for the ratio of lending to deposit interest rates. The adjusted noise-to-signal ratio can be used as a criterion for deciding which indicators to drop from the list of possible indicators. A signaling device that issues signals at random times (and thus has no intrinsic predictive power) would obtain (with a sufficiently large sample) an adjusted noise-to-signal ratio equal to unity. Therefore, those indicators with an adjusted noise-to-signal ratio equal to or higher than unity introduce excessive noise, and so are not helpful in predicting crises. Thus, on the basis of the results presented in Table 1, there are four indicators that should be removed from the list of those to be used within the signals approach. These indicators are the ratio of lending interest rates to deposit interest rates, bank deposits, imports, and the real interest rate differential.

Another way of interpreting the above results regarding the noisiness of the indicators is by comparing the probability of a crisis conditional on a signal from the indicator,  $A/(A+B)$  in terms of the above matrix, with the unconditional probability of a crisis— $(A+C)/(A+B+C+D)$  in terms of the above matrix. To the extent that the indicator has useful information, the conditional probability would be higher than the unconditional one. The sixth column of Table 1 presents the estimates of the conditional probabilities, while the seventh column shows the difference between the conditional and unconditional probabilities for each of the indicators. From these estimates, it is clear that the set of indicators for which the conditional probability of a crisis is lower than the unconditional probability is the same as the set for which the adjusted noise-to-signal ratio is higher than unity. In fact, it can be proven that the two conditions are equivalent.

### *How Leading Are the Leading Indicators?*

The previous discussion has ranked the indicators according to their ability to predict crises while producing few false alarms. However, such criteria are silent as to the lead time of the signal. From the vantage point of a policymaker who wants to implement preemptive measures, he/she will not be indifferent between an indicator that sends signals well before the crisis occurs and one that signals only when the crisis is imminent. In focusing on the 24-month window prior to the onset of the crisis, the criteria for ranking

Table 2. *Average Lead Time*

Indicator	Number of months in advance of the crisis when first signal occurs
Banking crisis	19
Real exchange rate	17
Real interest rate	17
Imports	16
M2 multiplier	16
Output	16
Bank deposits	15
“Excess” M1 balances	15
Exports	15
Terms of trade	15
International reserves	15
Stock prices	14
Real interest differential	14
M2/international reserves	13
Lending rate/deposit rate	13
Domestic credit/GDP	12

the indicators presented in Table 1 do not distinguish between a signal given 12 months prior to the crisis and one given one month prior to the crisis.

To examine this issue, we tabulated for each of the indicators considered the average number of months in advance of the crisis when the *first* signal occurs; this, of course, does not preclude the fact that the indicator may continue to give signals through the entire period immediately preceding the crisis. Table 2 presents the results. Indeed, the most striking fact about these results is that, on average, all the indicators send the first signal anywhere between a year and a year and a half before the crisis erupts, with banking sector problems (our second-ranked indicator) offering the longest lead time. Hence, on this basis, all the indicators considered are leading rather than coincident, which is consistent with the spirit of an “early warning system.”

#### *Persistence of the Signals*

Another desirable feature in a potential leading indicator is that signals be more persistent prior to crises (i.e., during the 24-month window) than at other times. To assess the behavior of the indicators in this regard, Table 3 presents a summary measure of the persistence of the signals (measured as the average number of signals per period) during the pre-crisis period relative to tranquil times.<sup>27</sup> As in the previous tables, the indi-

<sup>27</sup> Clearly, this concept of persistence is just another way of looking at the noisiness of the indicators; the measure in Table 3 is just the inverse of the adjusted noise-to-signal ratio.

Table 3. *Persistence of Signals*

Indicator	Persistence during crises relative to tranquil times
Real exchange rate	5.14
Banking crisis	2.90
Exports	2.37
Stock prices	2.15
M2/international reserves	2.07
Output	1.93
"Excess" M1 balances	1.92
International reserves	1.82
M2 multiplier	1.64
Domestic credit/GDP	1.62
Real interest rate	1.30
Terms of trade	1.29
Real interest differential	1.01
Imports	0.86
Bank deposits	0.84
Lending rate/deposit rate	0.59

cators are ranked according to their performance. For instance, for the real exchange rate, signals are more than five times more persistent prior to crises than in tranquil times. For most of the top-tier indicators, signals tend to be at least twice as persistent in precrisis periods relative to tranquil times.

The main conclusion that follows from the discussion above is that the signals approach can be useful as the basis for an early warning system of currency crises. Within this approach, a number of indicators have shown to be helpful in anticipating crises. Furthermore, the results from the signals approach are consistent with previous work on this subject, as many of the indicators that proved to be useful within this approach (including the real exchange rate, domestic credit, money, international reserves, exports, and output) also received support from the review of the empirical literature presented in Section II. From the vantage point of an early warning system, the results are encouraging in that the signaling, on average, occurs sufficiently early to allow for preemptive policy actions.

#### IV. Concluding Remarks

The studies reviewed in this paper indicate that an effective warning system for currency crises should take into account a broad variety of indicators, as these crises are usually preceded by symptoms that arise in a num-



ber of areas. Indicators that have proven to be particularly useful in anticipating crises include the behavior of international reserves, the real exchange rate, domestic credit, credit to the public sector, and domestic inflation. Other indicators that have found support include the trade balance, export performance, money growth, real GDP growth, and the fiscal deficit. The conclusions regarding the remaining indicators examined in this paper are necessarily tentative, in part because of the limited number of studies that formally tested their statistical significance in a variety of circumstances.

This paper has proposed a specific early warning system for currency crises. This system basically involves monitoring the behavior of a number of indicators, and recording the “signals” issued by these indicators as they move beyond certain threshold levels. In any given month, the system would estimate the probability of a crisis within the following 24 months conditional on the indicators issuing signals at that moment. Since the group of indicators that are issuing signals would be identified, this would provide information about the source and breadth of the problems that underlie the probability of a crisis. The evidence presented in this paper, based on the performance of individual indicators, has provided some support for the signals approach.

Future work on the signals approach could combine the information on the various indicators to estimate the probability of a crisis conditional on simultaneous signals from any subset of indicators. Constructing and evaluating the performance of composite indices also appear as natural extensions of this analysis.

Finally, it is important to recognize that while an early warning system would be a useful tool for a timely assessment of the likelihood of a currency crisis, any such system is also subject to limitations. There could be a number of issues, including of a political and institutional nature, that may be relevant for a particular country at a particular moment in time, and that are not incorporated in the warning system. A comprehensive assessment of the situation would necessarily need to take those issues into account. Only then would it be possible to have a coherent interpretation of events and a firm base for policy decisions.

## APPENDIX

Table A1. *Indicators of Crises: A Review of the Literature*

Study, sample, and frequency	Country coverage	Indicators	Comments
<b>Bilson (1979)</b> 1955–1977, annual	32 countries with emphasis on Ecuador, Mexico, and Peru. Devaluations of at least 5 percent.	(1) international reserves/base money (2) “shadow” exchange rate	Use (2) to assess the size of the devaluation and (1) as an indicator of the probability of a devaluation
<b>Blanco and Garber (1986)</b> 1973–1981, quarterly	Mexico	(1) domestic credit growth	Focuses on the one-step-ahead probability of devaluation, the expected exchange rate conditional on a devaluation, and the unconditional expected exchange rate.
<b>Calvo and Mendoza (1996)</b> 1983–1994, monthly and quarterly	Mexico	(1) M2 (in dollars)/reserves (2) money demand-supply gap	Stress on growing stock imbalances and maturity mismatches in the financial sector in explaining the crisis.
<b>Collins (1995)</b> 1979–1991, annual	18 countries with pegged exchange rates at the beginning of 1979.	(1) international reserves/GDP (2) real GDP growth (3) change in the real exchange rate (4) multiple exchange rate dummy (5) inflation (6) current account/GDP (7) foreign aid	(1)–(4) are used to determine the distance from the critical threshold at which a country devalues and (5)–(7) are used to determine the mean rate at which the economy is moving toward the critical level. The implied probabilities of exchange rate adjustment within 6 to 60 months are calculated.
<b>Cumby and Van Wijnbergen (1989)</b> 1979–1980, monthly	Argentina	(1) domestic credit growth	Focuses on the one-step-ahead probability of collapse.

Table A1. (continued)

Study, sample, and frequency	Country coverage	Indicators	Comments
<b>Dornbusch, Goldfajn, and Valdés (1995)</b> 1975–1995, annual and quarterly	Argentina, Brazil, Chile, Finland, and Mexico. Other currency crashes are also discussed.	(1) real exchange rate (2) real interest rates (3) GDP growth (4) inflation (5) fiscal deficit/ GDP (6) credit growth (7) trade balance/ GDP (8) current account/ GDP (9) international reserves (10) debt/GDP	While no formal tests are performed, the discussion focuses on the common patterns in the periods leading up to currency crises.
<b>Edin and Vredin (1993)</b> 1978–1989, monthly	Denmark, Finland, Sweden, and Norway. 16 devaluations, defined as shifts in the entire target zone.	(1) money (2) output (3) foreign interest rate (4) foreign price level (5) real exchange rate (6) international reserves/imports (7) trade balance	Estimate the one-step- ahead probability of devaluation, and the expected size of the devaluation (mea- sured as the change in the central parity of the target zone) con- ditional on a devalua- tion taking place.
<b>Edwards (1989)</b> 1962–1982, pooled quarterly and annual	39 devaluations; 24 developing countries with a fixed exchange rate for at least 10 years serve as the control group. The devaluations were at least 15 percent with respect to the U.S. dollar after having fixed the rate at least 2 years.	(1) central bank foreign assets/ base money (2) net foreign assets/M1 (3) domestic credit to public sector/ total credit (4) bilateral real exchange rate (5) parallel market premium (6) growth of credit (7) growth of credit to the public sector (8) public sector credit growth/ GDP (9) fiscal deficit/ GDP	The focus is on under- standing the causes of devaluations. (1)–(5) are used to estimate the probability of devaluation and (6)–(12) are used to describe the stylized facts of the 3 years preceding the devalu- ation.

Table A1. (continued)

Study, sample, and frequency	Country coverage	Indicators	Comments
<b>Edwards (1989)</b> <i>cont'd.</i>		(10) current account/GDP (11) terms of trade (12) errors and omissions plus short-term capital (13) exchange controls	
<b>Edwards and Montiel (1989)</b> 1962–82, annual	20 devaluations of at least 15 percent with respect to the U.S. dollar after having a fixed rate at least two years.	Same as (3)–(11) in Edwards (1989), and manufacturing real wages.	The stylized facts of 3, 1, and 0 years before the devaluation are described.
<b>Edwards and Santaella (1993)</b> 1954–1971, annual	48 devaluations (26 under an IMF program)	Same as (2)–(10) in Edwards (1989). (14) number of official exchange rates (15) political unpopularity (16) democracy (17) political violence (18) ideology (how leftist) (19) number of coups (20) relative GDP per capita	The evolution of (2)–(10) and (14) is compared for devaluers and nondevaluers. Some of these variables and (15)–(20) are used to estimate the probability of entering into an IMF program.
<b>Eichengreen, Rose, and Wyplosz (1995)</b> 1959–1993, quarterly	20 industrial countries; 78 crises, 33 successful attacks, and 45 successful defenses.	The authors mention that many of (1)–(16) are defined with respect to the same variable in Germany, but do not specify which of them. (1) change in international reserves (2) real effective exchange rate (3) credit growth (4) M1 growth (5) bond yield	The behavior of (1)–(16) is examined during the four years around crises and events compared to the evolution of these variables around periods of tranquility. “Events” include significant changes in exchange arrangements (such as devaluations, decisions to float, and widening of exchange rate bands);

Table A1. (continued)

Study, sample, and frequency	Country coverage	Indicators	Comments
<b>Eichengreen, Rose, and Wyplosz (1995)</b> <i>cont'd.</i>		(6) interest rates (7) stock prices (8) inflation (9) wage growth (10) GDP growth (11) unemployment rate (12) employment growth (13) fiscal deficit/GDP (14) current account/GDP (15) change in exports (16) change in imports (17) government victory (18) government loss (19) elections (20) change in government (21) capital controls (22) left-wing government (23) new finance minister (24) past exchange market crisis (25) past exchange market event	“crises” overlap with events but include unsuccessful speculative attacks and exclude changes in exchange arrangements not associated with market pressures. The association between (17)–(23) and foreign exchange market events is also examined. A subset of (1)–(25) is then used to estimate the <i>probability</i> of a successful defense, devaluation, revaluation, floating, fixing, and other events.
<b>Eichengreen, Rose, and Wyplosz (1996)</b> 1959–1993, quarterly	77 crises	(1)–(25) above plus a contagion variable that takes the value of one when any other country in the sample has a crisis	The aim is to establish, after controlling for fundamentals, whether a crisis elsewhere increases the probability of a crisis at home.
<b>Flood and Marion (1995)</b> 1957–1991, monthly	17 Latin American countries; 80 peg periods of a duration of at least 3 months.	(1) drift of the real exchange rate (2) variance of the real exchange rate	A model is developed and tested that examines the size and the timing of devaluations—that is, the duration of the peg; the focus is on trade-off between the cost

Table A1. (continued)

Study, sample, and frequency	Country coverage	Indicators	Comments
<b>Flood and Marion (1995)</b> <i>cont'd.</i>			of realigning and the costs of a misalignment.
<b>Frankel and Rose (1996)</b> 1971–1992, annual	105 developing countries; 117 devaluations of at least 25 percent; for high-inflation countries these must exceed the previous year by at least 10 percent.	(1) credit growth (2) fiscal deficit/GDP (3) per capita GDP growth (4) external debt/GDP (5) reserves/imports (6) current account/GDP (7) deviations from PPP in the bilateral real exchange rate (8) OECD GDP growth (9) foreign interest rate The following variables as a share of total debt: (10) commercial bank loans (11) concessional loans (12) variable rate debt (13) short-term debt (14) public sector debt (15) multilateral development bank loans (16) flow of FDI	(1)–(16) are examined to provide a broad characterization of currency crashes. The evolution of these indicators around crises is compared to the behavior during tranquil periods. The indicators are used to predict the probability of a crash.
<b>Goldfajn and Valdés (1998)</b> May 1985–May 1997, monthly	26 countries, alternative definitions of crises are considered.	(1) real exchange rate misalignment measures are obtained from a variety of univariate detrending methods as well as from estimating an equilib-	(1)–(2) are used to examine whether they have any predictive ability at a variety of time horizons.

Table A1. (continued)

Study, sample, and frequency	Country coverage	Indicators	Comments
<b>Goldfajn and Valdés (1998)</b> <i>cont'd.</i>		rium model (2) Financial Times Currency Forecaster series on market for- eign exchange expectations	
<b>Goldstein (1996)</b> annual and monthly	Argentina, Brazil, Chile, and Mexico. Other crises are also dis- cussed.	(1) international interest rates (2) mismatch be- tween the gov- ernment and banking sectors, short-term assets and liabilities (such as M3/ reserves) (3) current account/ GDP, particularly one driven by a fall in saving (4) boom in bank lending followed by a decline in asset prices (5) real exchange rate (6) short-term bor- rowing (7) weak banking sector	There are no formal tests, but (1)–(7) are used to discuss why some countries were more vulnerable than others in the wake of the Mexican crisis and the factors behind the crisis in Mexico.
<b>Humberto, Julio, and Herrera (1991)</b> monthly	Colombia	(1) credit growth (2) parallel market premium	Calculate the one-step- ahead probability of devaluation.
<b>Kamin (1988)</b> 1953–1983, annual	107 devaluations of at least 15 percent with respect to the U.S. dollar.	(1) trade balance/ GDP (2) import growth (3) export growth (4) capital flows/ GDP (5) changes in reserves (6) inflation (7) real exchange rate	The evolution of (1)–(9) is examined 3 years before and 4 years after the devaluations and is compared with the evolution of the same variables in the control group.

Table A1. (continued)

Study, sample, and frequency	Country coverage	Indicators	Comments
<b>Kamin (1988)</b> <i>cont'd.</i>		(8) real GDP growth (9) change in export prices	
<b>Kaminsky and Leiderman (forthcoming)</b> 1985–1987, monthly	Argentina, Israel, and Mexico	(1) monetary shocks (2) fiscal shocks (3) past inflation	Discuss the probability of crisis in exchange-rate-based stabilization programs.
<b>Kaminsky and Reinhart (1996)</b> 1970–1995, monthly	20 countries; 5 industrial and 15 developing; 76 currency crises and 26 banking crises	(1) export growth (2) import growth (3) bilateral real exchange rate—deviation from trend (4) terms of trade changes (5) changes in reserves (6) money demand/supply gap (7) changes in bank deposits (8) real interest rates (9) lending-deposit spread (10) domestic-foreign real interest rate differential (11) M2 money multiplier (12) M2/international reserves (13) growth in domestic credit/GDP (14) changes in stock prices (15) output growth (16) financial liberalization (17) banking crises	The behavior of (1)–(15) is examined 18 months before and after the crises and compared to the behavior of these indicators during “tranquil” periods. (16–17) are used in predicting the probability of crises. The usefulness of all the indicators is assessed by: (a) determining whether they gave a signal on a crisis-by-crisis basis; (b) tabulating the probability of crisis conditioned on a signal from the individual indicator; and (c) tabulating the probability of false signals.
<b>Klein and Marion (1994)</b> 1957–1991, monthly	87 peg episodes, as in Flood and Marion (1995).	(1) bilateral real exchange rates (2) real exchange rate squared	Using pooled data, (1)–(8) are used to estimate the probability of devaluation at $t + 1$ ;

(continued)



Table A1. (continued)

Study, sample, and frequency	Country coverage	Indicators	Comments			
<b>Klein and Marion (1994)</b> <i>cont'd.</i>		(3) net foreign assets of the monetary sector/M1	the sample is disaggregated into pre- and post-Bretton Woods period and distinctions are made between pegs that are followed by either a float or a crawling peg from devaluations followed by a new peg.			
		(4) net foreign assets of the monetary sector/M1 squared				
		(5) openness				
		(6) trade concentration				
		(7) regular executive transfers				
		(8) irregular executive transfers				
		(9) months spent in the peg				
		<b>Krugman (1996)</b> 1988–1995, annual, quarterly, some daily		France, Italy, Spain, Sweden, and the United Kingdom during the 1992–93 ERM crises.	(1) unemployment rate	While the bulk of the paper is theoretical, evidence on the trends of (1)–(4) is used to support the argument that the ERM episode does not provide evidence of self-fulfilling crises.
					(2) output gap	
(3) inflation						
(4) public debt/GDP						
<b>Milesi-Ferretti and Razin (1996)</b> 1970–1994, annual	Chile and Mexico have the 4 crises cases; Ireland, Israel, and South Korea are no-crisis cases due to policy reversal; and Australia is no crisis case with no policy change.	(1) debt service/GDP adjusted for GDP growth and changes in the real exchange rate	The emphasis is on developing a notion of current account sustainability and the factors it depends on. While there is no formal test, (1)–(8) are used to compare the crisis and no-crisis episodes.			
		(2) exports/GDP				
		(3) real exchange rate versus historical norm				
		(4) saving/GDP				
		(5) fiscal stance				
		(6) fragility of the banking sector				
		(7) political instability				
		(8) composition of capital flows				

(continued)

Table A1. (continued)

Study, sample, and frequency	Country coverage	Indicators	Comments
<b>Milesi-Ferretti and Razin (1998)</b> 1970–1996	105 low- and middle-income countries. Four definitions of currency crashes capturing different magnitudes of depreciation. Ranging from 119 to 172 crashes, depending on which definition is used.	(1) GDP growth (2) investment (3) GDP (4) openness index (5) reserves/imports (6) reserves/M2 (7) external debt/exports (8) external debt/GDP (9) interest payments on external debt/GDP (10) concessional debt/total debt (11) public debt/total debt (12) short-term debt/total debt (13) FDI/GDP (14) net portfolio flows/GDP (15) U.S. real interest rate (16) GDP growth in OECD countries (17) dummy variable for pegged exchange rate (18) IMF program (19) official transfers	The approach is to use (1)–(19) as regressors in a probit estimation in which the dependent variables considered are dummy variables based on the four definitions of currency crises. The paper also examines the determinants of current account reversals.
<b>Moreno (1995)</b> 1980–94, monthly and quarterly	Indonesia, Japan, Malaysia, Philippines, Singapore, Korea, and Thailand. 126 episodes of speculative pressures; 72 in the direction of depreciation; and 54 in the direction of appreciation.	(1) change in bilateral exchange rate (2) changes in net foreign assets (central bank) (3) domestic-foreign interest rate differential (4) exports/imports (5) output gap All the following are relative to the United States:	The emphasis is on testing whether the behavior of macroeconomic variables (4)–(10) differs between “tranquil” and “speculative” periods. (1)–(3) are used to define such periods.

Table A1. (continued)

Study, sample, and frequency	Country coverage	Indicators	Comments
<b>Moreno (1995)</b> <i>cont'd.</i>		(6) growth of domestic credit/ reserve money (7) growth in M1 (8) growth in broad money (9) fiscal deficit/ government spending (10) inflation	
<b>Ötker and Pazarbaşıoğlu (1994)</b> 1979–1993, monthly	Denmark, Ireland, Norway, Spain, and Sweden. The sample covers 15 devaluations and 10 realignments of all central rates.	(1) domestic credit (2) real effective exchange rate (3) trade balance (4) unemployment rate (5) German price level (6) output (7) reserves (8) central parity (9) foreign-domestic interest rate differential (10) position within band	The aim is to use (1)–(10) to estimate the probability of abandoning the peg by either devaluing or floating. (1)–(8) are associated for macroeconomic “fundamentals” while (7), (9), and (10) are proxies for “speculative factors.”
<b>Ötker and Pazarbaşıoğlu (1996)</b> 1982–1994, monthly	Mexico. During the sample there are 4 devaluations; 3 increases in the rate of crawl, and 2 reductions; and 2 shifts to a more flexible exchange system.	(1) real exchange rate (2) international reserves (3) inflation differential with the United States (4) output growth (5) U.S. interest rates (6) central bank credit to the banking system (7) financial sector reform dummy (8) share of short-term foreign currency debt	(1)–(10) are used to estimate the one-step-ahead probability of a regime change. The relative importance of the indicators is assessed for pre- and post-November 1991, when the dual exchange rate system was abandoned.

Table A1. (concluded)

Study, sample, and frequency	Country coverage	Indicators	Comments
<b>Ötker and Pazarbaşıoğlu (1996) cont'd.</b>		(9) fiscal deficit (10) current account balance	
<b>Sachs, Tornell, and Velasco (1995)</b> 1985–95, monthly and annual	20 emerging market countries.	(1) real exchange rate (2) credit to the private sector/ GDP (3) M2/international reserves (4) saving/GDP (5) investment/GDP (6) capital inflows/ GDP (7) short-term capital inflows/GDP (8) government consumption/ GDP (9) current account/ GDP	The emphasis is on explaining why some countries were more affected by the Mexican crisis than others.

Note: Additional details on the individual countries included in the larger cross-country studies are available in the original studies.

Table A2. *Indicators by Category*

Sector	Indicators	
<b>External</b>		
Capital account	(1) international reserves/base money (2) international reserves/GDP (3) stock of international reserves (4) reserves/imports (5) growth in reserves (6) central bank foreign assets/base money (7) growth of central bank net foreign assets (8) net foreign assets/M1 (9) net foreign assets/M1 squared	(10) errors and omissions plus short-term capital (11) share capital flows in the form of short-term borrowing (12) short-term capital flows/GDP (13) FDI/debt (14) capital account balance/GDP (15) domestic-foreign real interest rate differential (16) domestic-foreign nominal interest rate differential
Debt profile	(1) foreign aid (2) external debt/GDP (3) public debt/GDP (4) share of commercial bank loans (5) share of concessional loans (6) share of variable-rate debt	(7) share of short-term debt (8) share of public sector debt (9) share of multilateral development bank loans (10) debt service/GDP adjusted for GDP growth
Current account	(1) change in the real exchange rate (2) level of the real exchange rate (3) drift of the real exchange rate (4) variance of the real exchange rate (5) deviations from PPP in the real bilateral exchange rate (6) deviations from trend in the real exchange rate (7) deviations from historical average of the real exchange rate (8) real exchange rate squared	(9) trade balance/GDP (10) current account/GDP (11) exports/GDP (12) exports/imports (13) change in exports (14) change in imports (15) saving/GDP (16) investment/GDP (17) change in the terms-of-trade (18) change in export prices (19) exchange rate expectations
International	(1) OECD real GDP growth (2) international interest rates	(3) U.S. interest rates (4) foreign price level
<b>Financial</b>		
Financial liberalization	(1) real interest rates (2) credit growth (3) growth in credit/GDP (4) lending-deposit interest rate spread	(5) growth in M2 multiplier (6) growth of credit/reserve money relative to the United States

Table A2. (concluded)

Sector	Indicators	
<b>Other financial</b>	(1) "shadow" exchange rate (2) parallel market premium (3) central parity (4) position within the band (5) central bank credit to the banking system (6) money demand-supply gap (7) M1 growth  (8) M1 level	(9) M1 growth relative to the United States (10) broad money growth relative to the United States (11) change in bank deposits (12) bond yields (13) inflation (14) inflation relative to the United States (15) M2/international reserves
<b>Real sector</b>	(1) real GDP growth (2) per-capita growth (3) output level (4) output gap (5) manufacturing real wages	(6) wage growth (7) unemployment rate (8) employment growth (9) changes in stock prices
<b>Fiscal</b>	(1) fiscal deficit/GDP (2) fiscal deficit/government spending relative to the United States (3) government consumption/GDP	(4) domestic credit to public sector/total credit (5) growth in public sector credit (6) public sector credit growth/GDP
<b>Institutional/structural</b>	(1) multiple exchange rate dummy (2) exchange controls dummy (3) relative GDP per capita (4) financial liberalization dummy (5) banking crisis dummy	(6) openness  (7) trade concentration (8) months spent on peg (9) past foreign exchange market crisis (10) past foreign exchange market event
<b>Political</b>	(1) government victory dummy (2) government loss dummy (3) elections (4) change in government (5) legal executive transfers	(6) illegal executive transfers (7) degree of political instability (8) left-wing government (9) new finance minister
<b>Contagion</b>	(1) crisis elsewhere	

Table A3. *Indicators of Crises: What Worked Best?*

Study	"Preferred" indicators	Comments	Other issues
<b>Bilson (1979)</b>	(1) international reserves/base money	The probability of a devaluation one year increases from about 5 percent for countries in which (1) is 30 percent or greater, to 40 percent for countries where (1) is less than 10 percent.	The shadow exchange rate appears to have some predictive power, but no formal tests are conducted.
<b>Collins (1995)</b>	(1) international reserves/GDP (2) real GDP growth (3) inflation	(1) is the key determinant of the distance from threshold; (2) is marginally significant; (3) is the key determinant of the mean rate at which the economy is moving toward the critical level.	The remaining 4 variables were statistically insignificant. The model worked best in predicting exchange rate adjustments within 12 months; countries that actually adjusted showed an estimated probability of 46 percent versus a 28 percent probability for those that did not adjust.
<b>Edin and Vredin (1993)</b>	(1) money (2) output (3) international reserves/imports	(1)–(3) have a significant effect on the probability of devaluation. (1), (2), and the real exchange rate have a significant effect on the size of the devaluation.	The remaining variables were statistically insignificant. The estimates of the probability of devaluation seem robust, but those of the size of devaluations are much less robust.
<b>Edwards (1989)</b>	(1) central bank foreign assets/base money (2) net foreign assets/M1	(1)–(5) have the predicted effects on the probability of a devaluation, and (6)–(10) are signif-	The remaining variables were not significantly different across the two groups of coun-

Table A3. (continued)

Study	"Preferred" indicators	Comments	Other issues
<b>Edwards (1989)</b> <i>cont'd.</i>	(3) domestic credit to public sector/total credit (4) bilateral real exchange rate (5) parallel market premium (6) growth of credit (7) growth of credit to the public sector (8) public sector credit growth/GDP (9) fiscal deficit/GDP (10) current account/GDP	icantly different for the devaluers than for the control group.	tries. Since the data are annual and the variables are lagged one period, these are one-year-ahead predictions.
<b>Eichengreen, Rose, and Wyplosz (1995)</b>	(1) inflation (2) employment growth (3) current account/GDP (4) capital controls (5) government loss (6) past foreign exchange market crisis	(1)–(6) were statistically significant in the multivariate analysis that estimates the probability of a (successful or unsuccessful) attack.	The variables that were not significant in the estimation of the probability of an attack include credit growth, GDP growth, unemployment rate, fiscal deficit/GDP, government victory, and past foreign exchange market events.
<b>Eichengreen, Rose, and Wyplosz (1996)</b>	In addition to those in their earlier study, (1) contagion dummy	(1) was statistically significant with the anticipated sign. A crisis elsewhere increases the probability of a crisis at home.	Their results show trade links are the more important conduit of contagion.
<b>Flood and Marion (1995)</b>	(1) drift of the real exchange rate (2) variance of the real exchange rate	The size of the devaluation and the duration of the peg are significantly determined	The overall fit of the equations (1)–(2) does better predicting the size of the devaluation than



Table A3. (continued)

Study	"Preferred" indicators	Comments	Other issues
<b>Flood and Marion (1995)</b> <i>cont'd.</i>		by (1)–(2) with the signs predicted by theory.	the time spent in peg, where the share of the explained variation is 35 percent or less, depending on the specification.
<b>Frankel and Rose (1996)</b>	(1) concessional debt/total debt (2) public sector debt/total debt (3) foreign direct investment/total debt (4) overvaluation of the real exchange rate (5) reserves/imports (6) foreign interest rate (7) credit growth	(1)–(7) help predict crises one year in advance. All the variables have the expected signs. Increases in (2), (4), (6), and (7) increase the probability of a crash; increases in (1), (3), and (5) have the opposite effect.	The remaining indicators were not significant in the multivariate probit estimation of the one-step-ahead probability of a crash. Only 5 of 69 crises were predicted by the model.
<b>Goldfajn and Valdes (1998)</b>	(1) various measures of real exchange rate misalignment	(1), overvaluations, help predict crises.	Market-based exchange rate expectations do not help predict crises, irrespective of which definition of crisis was used or which forecast horizon.
<b>Kamin (1988)</b>	(1) trade balance/GDP (2) export growth (3) import growth (4) real exchange rate (5) real GDP growth (6) inflation	The evolution of (1)–(6) is significantly different for the devaluers than for the control group during 3 years to 1 year before devaluation.	The paper also examines the evolution of the indicators in the postdevaluation period.
<b>Kaminsky and Reinhart (1996)</b>	(1) export growth (2) bilateral real exchange rate—deviation from trend	In 3/4 of the crises at least 60 percent of the indicators were giving a signal. External sector	The indicators are compared on the basis of the percent of crises accurately called

Table A3. (continued)

Study	"Preferred" indicators	Comments	Other issues
<b>Kaminsky and Reinhart (1996)</b> <i>cont'd.</i>	(3) terms of trade changes (4) changes in reserves (5) money demand/supply gap (6) real interest rates (7) M2 money multiplier (8) M2/international reserves (9) growth in domestic credit/GDP (10) changes in stock prices (11) output growth (12) banking crises	variables and those linked to financial liberalization provided the most accurate signals during the 12 months before the crises. Banking crises help predict the probability of a balance of payments crisis.	and on the noise-to-signal ratio. (1), (6), and (8) have the highest share of accurately called crises while (2) has the lowest noise-to-signal ratio.
<b>Klein and Marion (1994)</b>	(1) bilateral real exchange rates (2) real exchange rate squared (3) net foreign assets of the monetary sector/M1 (4) net foreign assets of the monetary sector/M1 squared (5) openness (6) irregular (7) regular executive transfers (8) months spent in the peg	(1)–(8) affect the probability that the peg will be abandoned; the significance of (2), (4), and (7) is particularly sensitive to the specification used.	
<b>Milesi-Ferretti and Razin (1998)</b>	(1) reserves/imports (2) reserves/M2 (3) terms of trade (4) OECD growth (5) official transfers	(1)–(10) are significant in three or more specifications. Only (1), (2), (4), (7), and (8) are robust in all the specifications	The analysis suggests that currency crashes are more likely when external conditions are unfavorable, reserves are low,

(continued)

Table A3. (continued)

Study	"Preferred" indicators	Comments	Other issues
<b>Milesi-Ferretti and Razin (1998)</b> <i>cont'd.</i>	(6) openness (7) foreign real interest rates (8) real exchange rate overvaluation (9) concessional debt (10) FDI/GDP	and definitions of crises used.	and the exchange rate is overvalued. Their results also suggest that current account reversals are very different from currency crashes.
<b>Moreno (1995)</b>	(1) growth in broad money relative to the United States (2) fiscal deficit (3) output (4) inflation	The differences were significant for periods where speculative pressures were in the direction of depreciation. If Japan is excluded from the sample, (2) is not significantly different from tranquil periods.	The analysis is contemporaneous, or uses only one month before the speculative attack; hence, the analysis does not say much about whether the indicators behave differently in the periods leading up to the crisis.
<b>Ötker and Pazarbaşıoğlu (1994)</b>	(1) domestic credit (2) real effective exchange rate (3) trade balance (4) foreign-domestic interest rate differential (5) unemployment rate (6) German price level (7) output (8) international reserves (9) central parity (10) position within the band	The importance of the variables varied across countries in individual country regressions. In a regression including all countries (except Denmark, because it had no devaluation), the significant variables were (2), (4), (5), (6), and (10).	The estimated probability of devaluation increases markedly ahead of devaluations.
<b>Ötker and Pazarbaşıoğlu (1996)</b>	(1) real exchange rate (2) international reserves	(1)–(5) explain the probability of a devaluation; the remaining vari-	The role of (4) becomes more important while the role of (5)

Table A3. (concluded)

Study	"Preferred" indicators	Comments	Other issues
<b>Ötker and Pazarbaşıoğlu (1996), cont'd.</b>	(3) inflation differential with the United States (4) central bank credit to the banking system (5) fiscal deficit (6) financial sector reform interaction dummy	ables were not statistically significant. The interaction of (1)–(5) with (6) was significant, suggesting a structural change.	becomes less so in forecasting the December 1994 crisis. The predictive capacity of the model forecasting crisis 6 months ahead deteriorates considerably.
<b>Sachs, Tornell, and Velasco (1995)</b>	(1) change in real exchange rate (2) change in credit to the private sector/GDP (3) M2/international reserves (4) short-term capital inflows/GDP (5) government consumption/GDP	(1)–(2) are used to define whether the "fundamentals" are weak or strong, and (3) is used to define whether reserves are low or high. The simultaneous combination of weak fundamentals and low reserves made countries vulnerable to contagion effects following the Mexican crisis. (4) and (5) also had an effect, but only in the presence of weak fundamentals and low reserves.	The remaining indicators were statistically insignificant. The exercise was intended to assess the factors that made countries vulnerable following the Mexican crisis. However, it does not assess the indicator properties of the variables in predicting individual crises within the 1986–95 sample analyzed.

Table A4. *Performance of Indicators*

Sector	Variables	Number of studies considered	Statistically significant results
Capital account	international reserves	12	11
	short-term capital flows	2	1
	foreign direct investment	2	2
	capital account balance	1	—
	domestic-foreign interest differential	2	1
Debt profile	foreign aid	1	—
	external debt	2	—
	public debt	1	—
	share of commercial bank loans	1	2
	share of concessional loans	2	2
	share of variable-rate debt	2	—
	share of short-term debt	2	—
	share of multilateral development bank debt	1	—
Current account	real exchange rate	14	12
	current account balance	7	2
	trade balance	3	2
	exports	3	2
	imports <sup>a</sup>	2	1
	terms of trade	3	2
	export prices	1	—
	savings	1	—
	investment	2	—
	exchange rate expectations	1	—
	International	foreign real GDP growth	2
foreign interest rates		4	2
foreign price level		2	1
Financial liberalization	real interest rates	1	1
	credit growth	7	5
	lending-deficit interest spread	1	—
	money multiplier	1	1
Other financial	parallel market premium	1	1
	central parity	1	1
	position within the band	1	1
	money demand-supply gap	1	1
	change in bank deposits	1	—
	central bank credit to banks	1	1
	money	3	2
Real sector	M2/international reserves	3	3
	inflation <sup>b</sup>	5	5
	real GDP growth or level	9	5

Table A4. (concluded)

Sector	Variables	Number of studies considered	Statistically significant results
	output gap	1	1
	employment/unemployment <sup>c</sup>	3	2
	change in stock prices	1	1
Contagion	crisis elsewhere dummy	1	1
Fiscal	fiscal deficit	5	3
	government consumption	1	1
	credit to public sector	3	3
Institutional/ structural	multiple exchange rates	1	—
	exchange/capital controls <sup>d</sup>	2	1
	openness	1	1
	trade concentration	1	—
	banking crisis	1	1
	financial liberalization	2	1
	months spent on peg	1	1
	past foreign exchange market crisis <sup>e</sup>	1	1
	past foreign exchange market event <sup>f</sup>	1	—
Political	government victory	1	—
	government loss	1	1
	legal executive transfer	1	1
	illegal executive transfer	1	1

<sup>a</sup>In the statistically significant results, the rate of growth of imports declines prior to a devaluation.

<sup>b</sup>In one of the statistically significant results, an increase in inflation reduces the probability of an attack.

<sup>c</sup>In one of the statistically significant results, an increase in employment increases the probability of an unsuccessful attack.

<sup>d</sup>In the statistically significant result, the presence of capital controls increases the probability of an unsuccessful attack and reduces the probability of a successful attack.

<sup>e</sup>A past foreign exchange market crisis reduces significantly the possibility of an unsuccessful attack, and increases marginally the possibility of a successful one.

<sup>f</sup>Events include significant changes in exchange arrangements (such as devaluations, revaluations, decisions to float, and widening of exchange rate bands); crises overlap with events but include unsuccessful speculative attacks and exclude changes in exchange arrangements not associated with market pressure.

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