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Currency crises: Are they all the same?☆

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Abstract

The plethora of currency crises around the world has fueled many theories on the causes of speculative attacks. The first-generation models focus on fiscal problems while the second-generation models emphasize countercyclical policies and self-fulfilling crises. In the 1990s, models pinpoint to financial excesses. With the crisis of Argentina in 2001, models of sovereign default have become popular again. While the theoretical literature has emphasized variety, the empirical literature has supported the "one size fits all" models. This paper contributes to the empirical literature by assessing whether the crises of the last 30 years are of different varieties.

JEL classification: F30; F31; F32; F34; F36; F41

Keywords: Currency crises; Current account problems; Over-borrowing syndrome; Sovereign debt crises; Sudden stops; Self-fulfilling crises; Early warnings of crises

1. Introduction

The plethora of financial crises that have ravaged emerging markets and mature economies since the 1970s has triggered a variety of theories on the causes of speculative attacks.

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Models are even catalogued into three generations. The first-generation models focus on the fiscal and monetary causes of crises. These models were mostly developed to explain the crises in Latin America in the 1960s and 1970s. The second-generation models aim at explaining the EMS crises of the early 1990s. Here the focus is mostly on the effects of countercyclical policies in mature economies and on self-fulfilling crises, with rumors unrelated to market fundamentals at the core of the crises. The next wave of currency crises, the Tequila crisis in 1994 and the so-called Asian Flu in 1997, fueled a new variety of models – also known as third-generation models, which focus on moral hazard and imperfect information. The emphasis here has been on "excessive" booms and busts in international lending and asset price bubbles. With the crisis in Argentina in 2001, academics and economists at international institutions are now dusting off the articles of the 1980s modeling crises of default.

The abundance of theoretical models has failed to generate the same variety of empirical models. Most of the previous empirical research groups together indicators capturing fiscal and monetary imbalances, economic slowdown, and the so-called over-borrowing syndrome to predict crises.[1] While this research has certainly helped to capture the economic fragility at the onset of crises and therefore to predict balance-of-payment problems, it has failed to identify the changing nature of crises and to predict those crises that do not fit a particular mold. This paper contributes to this literature by assessing whether the crises of the last 30 years are of different varieties. As a by-product, this paper contributes to the early warning literature by providing new forecasts of the onset of financial crises.

To identify the various classes of crises, I examine crisis episodes for 20 industrial and developing countries. The former include: Denmark, Finland, Norway, Spain, and Sweden. The latter focus on: Argentina, Bolivia, Brazil, Chile, Colombia, Indonesia, Israel, Malaysia, Mexico, Peru, the Philippines, Thailand, Turkey, Uruguay, and Venezuela. The period covered starts in January 1970 and includes crises up to February 2002, with a total of 96 currency crises. To gauge whether crises are all of the same nature or whether groups of crises show unique features, I use a variety of macroeconomic and financial indicators suggested by the previous literature – totaling 18 variables – and a multiple-regime variant of the signals approach, which allows to endogenously identify the existence of various classes of crises.[2] Once crises are classified, I examine whether the nature of crises varies across emerging and mature economies and tally the degree of severity of each type of crisis.

The key finding is that, in fact, crises have not been created equal. Crises are found to be of six varieties. Four of those varieties are associated with domestic economic fragility, with vulnerabilities related to current account deterioration, fiscal imbalances, financial excesses, or foreign debt unsustainability. But crises can also be provoked by just adverse world market conditions, such as the reversal of international capital flows. The so-called sudden-stop phenomenon identifies the fifth variety of crises. Finally, as emphasized by the second-generation models, crises also happen in economies with immaculate fundamentals. Thus, the last variety of crises is labeled self-fulfilling crises.

The second finding is that crises in emerging markets are of a different nature than those in mature markets. Crises triggered exclusively by adverse shocks in international capital markets

[1] See, for example, Berg and Patillo (1999), Eichengreen et al. (1995), Frankel and Rose (1996), Kaminsky (1998), and Sachs et al. (1996).

[2] See Kaminsky (1998) and Kaminsky and Reinhart (1999) for an application of the one-regime signals approach to forecasting crises.

and crises in economies with immaculate fundamentals are found to be a mature-market phenomenon. In contrast, crises in emerging economies are triggered by multiple vulnerabilities.

The last finding concerns the degree of severity of crises. As it is conventional in the literature, severity is measured by output losses following the crises, the magnitude of the reserve losses of the central bank, and the depreciation of the domestic currency. I also estimate a variety of measures capturing the extent of borrowing constraints/lack of access to international capital markets following crises. Notably, the degree of severity of crises is closely linked to the type of crises, with crises of financial excesses scoring worst in this respect.

The rest of the paper is organized as follows. Section 2 reviews the literature on crises and examines the particular symptoms associated with each model. Section 3 examines the multiple-regime signals approach. Section 4 is the main part of the paper and examines the characteristics of crises in the 20 countries in the sample. The section pays particular attention to the types of crises that have afflicted mature and emerging markets. It also tallies the severity of the various classes of crises. Section 5 examines the early warnings of crises implicit in this approach. Section 6 concludes.

2. Models of currency crises

The earlier models of balance-of-payments problems were inspired by the Latin American style of currency crises of the late 1960s and early 1970s. In these models, unsustainable money-financed fiscal deficits lead to a persistent loss of international reserves and ultimately ignite a currency crash (see, for example, Krugman, 1979; Lahiri and Végh, 2003). Stimulated by the EMS collapses in 1992 and 1993, more recent models of currency crises have stressed that the depletion of international reserves might not be at the root of currency crises. Instead, these models focus on government officials' concern on, for example, unemployment. Governments are modeled facing two often conflicting targets: reducing inflation and keeping economic activity close to a given target. Fixed exchange rates may help in achieving the first goal but at the cost of a loss of competitiveness and a recession. With sticky prices, devaluations restore competitiveness and help in the elimination of unemployment, thus prompting the authorities to abandon the peg during recessions.[3]

The crises in Latin America in the 1980s, the Nordic countries in 1992, Mexico in 1994, and Asia in 1997 have prompted the economics profession to model the effects of banking problems on balance-of-payments difficulties. For example, Diaz-Alejandro (1985) and Velasco (1987) model difficulties in the banking sector as giving rise to a balance-of-payments crisis, arguing that if central banks finance the bailout of troubled financial institutions by printing money, we have the classical story of a currency crash prompted by excessive money creation. Within the same theme, McKinnon and Pill (1995) examine the role of capital flows in an economy with an unregulated banking sector with deposit insurance and moral hazard problems of the banks. Capital inflows in such an environment can lead to over-lending cycles with consumption booms and exaggerated current account deficits. Most of the times, the over-lending cycles are also accompanied by booms in the stock and real estate markets. In turn, the over-borrowing cycles lead to real exchange rate appreciations, losses of competitiveness, and slowdowns in growth. As the economy enters a recession, the excess lending during the boom makes banks more prone to a crisis when a recession unfolds. This state of business becomes even more complicated by the pervasive over-exposure of financial institutions to the stock and real estate

[3] See, for example, Obstfeld (1994, 1996).

markets, which makes banks even more vulnerable when asset bubbles burst as the recession approaches. The deterioration of the current account, in turn, makes investors worried about the possibility of default on foreign loans. In turn, the fragile banking sector makes the task of defending the peg more difficult and may lead to the eventual collapse of the domestic currency. In a similar vein, Goldfajn and Valdés (1997) show how changes in international interest rates and capital inflows are amplified by the intermediation role of banks and how such swings may also produce an exaggerated business cycle that ends in bank runs and financial and currency crashes.

More recently, the literature on capital inflows and capital inflow problems has suggested another potential source of instability (see, for example, Calvo, 1998; Calvo and Reinhart, 2000; Calvo et al., 2003), that of liquidity crises due to sudden reversals in capital flows. For example, the debt crisis in 1982, the Mexican crisis in 1994 and the so-called Tequila effect, and the Asian crisis in 1997–1998 show that capital inflows can come to a sudden stop and even can sharply reverse their course and become capital outflows. As emphasized by those authors, the sudden reversal, prompted, in large part, by fluctuations in interest rates in industrialized countries, is far more persistent and severe when the borrowing country is an emerging economy, highly indebted, dollarized, and with debt concentrated at short maturities. In these cases, sudden stops trigger massive depreciations of the domestic currency.

The now revitalized literature on sovereign default has been mostly concerned with the ability or the willingness of a country to service the debt. This literature mostly developed in the 1980s following the debt crisis in 1982. In a seminal contribution, Eaton and Gersowitz (1981) argue that sovereign lending can take place even if borrowers are immune to any direct actions by creditors in the event of no repayment. In this approach, borrowers will not be tempted to default if they are concerned that they will lose their reputation in international credit markets and lose future access to borrowing. In contrast, Cohen and Sachs (1986) assume that if a country fails to make repayments, it will suffer a loss that is proportional to the country's output, perhaps because creditors can enforce repayment through direct punishments such as disturbing the international trade of any borrower that unilaterally defaults. The literature on sovereign crises has continued to grow, with the empirical research emphasizing that defaults are more likely if the level of debt and the interest rates at which the countries borrow are high or if there are adverse output shocks, such as deterioration in the country's terms of trade.[4]

3. Capturing varieties: methodology

The empirical research on predicting currency crises has adopted a variety of econometric techniques. Parametric techniques include probit and VAR models. Non-parametric techniques are mostly confined to the leading-indicator methodology. While currency crises can take many forms, all the estimations impose "the one size fits all" approach, with the indicators predicting crises including indicators related to sovereign defaults, such as high foreign debt levels, or indicators related to fiscal crises, such as government deficits, or even indicators related to crises of excesses, such as stock and real estate market booms and busts. That is, in all cases, researchers impose the same functional form to all observations. When some indicators are not robustly linked to all crises, they tend to be discarded even when they may be of key importance for a subgroup of observations. Still, there is evidence that the nature of crises has changed. For

[4] More recently, Reinhart et al. (2003) have emphasized the role of countries' default and inflation history in explaining debt problems.

example, as examined in Kaminsky and Reinhart (1999), financial market booms and busts are an important trigger of crises after financial liberalization but the deterioration of the current account is at the core of crises before financial liberalization. Naturally, if these non-linearities are known, they can be controlled using interactive terms. Yet, such knowledge is the exception rather than the rule.

Another source of non-linearities impossible to capture in a standard regression framework or signals approach is that crises become more likely as the number of fragilities increases. For example, a real exchange appreciation of a certain magnitude becomes more worrisome if coupled with excessive monetary expansion. Similarly, high foreign debt leads to a further deterioration of the economy if accompanied by high world real interest rates.

In this paper, I use a different methodology to allow for ex-ante unknown non-linearities. This methodology is a modification of the conventional leading-indicator methodology, which has a long history in the rich literature that evaluates the ability of macroeconomic and financial time series to predict business cycle turning points (see, for instance, Stock and Watson, 1989 and Diebold and Rudebusch, 1989) and more recently has been also applied to predict crises. The basic idea in the leading-indicator methodology is that the economy evolves through phases of booms and recessions or, in our case, of tranquil times and crisis episodes and that some fundamentals start to behave differently at the onset of a recession or a crisis and thus can be used to predict the change in regime. This change in behavior of a particular series is captured empirically by finding a ''threshold'' that turns a fluctuation of a given variable into a signal of an upcoming recession or crisis. In most of the applications, this threshold is the one that minimizes the noise-to-signal ratio of the particular indicator. In this methodology, the working assumption is that recessions or crises are just of one type.[5] Moreover, thresholds are obtained indicator by indicator without consideration of possible complementarities. In contrast, the proposed new methodology allows the data to determine the number and characteristics of classes of crises.[6] Also, the thresholds that turn a fluctuation of a variable into a signal of an upcoming crisis will be identified jointly for all indicators to allow for interdependence.

To identify the possible multiple varieties of crises, I apply regression-tree analysis.[7] This technique[8] allows one to search for an unknown number of sample splits (in our case, varieties of crises and of tranquil times) using multiple indicators. Breiman et al. (1984) show that the regression-tree method is consistent in the sense that, under suitable regularity conditions, the estimated piecewise linear regression function converges to the best nonlinear predictor of the dependent variable of interest. The actual sorting algorithm is described in Durlauf and Johnson (1995). Intuitively, this methodology behaves as a multiple-regime signals approach.[9] To identify the types of crises, the observations are first divided into those observations in periods of crises and observations of tranquil times.[10] Crisis times are identified with a 1 while tranquil times are identified with a 0. As in the conventional signal approach, the

[5] Also, booms or ''tranquil times'' are assumed to be of just one type.

[6] This methodology can be thought of as the non-parametric alternative to the multiple-regime Markov-process models pioneered by Hamilton (1989). However, in contrast to the multiple-regime Markov-process model, the number of regimes does not need to be specified exogenously, it can be determined endogenously.

[7] See Durlauf and Johnson (1995) and Gosh and Wolf (1998) for applications of the regression-tree analysis to characterize multiple regimes in growth behavior.

[8] See Breiman et al. (1984) for a description of this technique.

[9] See Kaminsky (1998) for a discussion of the one-regime signals approach.

[10] Observations are catalogued into crisis times and tranquil times using an index of exchange market pressure. See Kaminsky and Reinhart (1999) for a detailed explanation of the identification of crises.

algorithm first chooses thresholds for each indicator to minimize its noise-to-signal ratio.[11] Then, the indicator with the lowest noise-to-signal ratio is selected. All observations are then separated into two groups: those for which the chosen indicator is signaling and those for which the indicator is not signaling. For each group, the methodology is repeated. Again, for each of the remaining indicators, new thresholds are selected to minimize the noise-to-signal ratio. Note that this time the threshold that converts a fluctuation of an indicator into a signal of an upcoming crisis is conditioned on the selection of the first indicator and its threshold. This allows us to find complementarities: for example, even minor fiscal problems can add to fragility and trigger crises if accompanied by vulnerability of the banking sector. In this second round, groups are created based on the classification of the indicator with the lowest noise-to-signal ratio from all remaining indicators.[12] This process continues, with each new round helping to classify observations into more tightly defined groups. Obviously, this process can continue until each observation is classified into a different type. To avoid the perfect fit, the regression-tree analysis imposes a penalty on the number of varieties. As explained in Gosh and Wolf (1998), the rule used resembles an adjusted R^2 criterion, with the improvement due to the identification of a new variety being compared with a penalty on the number of varieties. If the penalty exceeds the improvement, the algorithm chooses the previous number of varieties; otherwise the algorithm continues to partition the sample. Still, no asymptotic theory exists to test the statistical significance of the number of regimes uncovered by the regression tree. Finally, it should be noted that the algorithm classifies both crisis episodes and tranquil times.

4. The anatomy of currency crises

The regression-tree methodology was applied to the data and the results of this exercise are described below. First, the data and the estimated classification are presented. Afterwards, the discussion is organized so as to answer the following questions: What are the varieties of financial crises that we observe in this sample of over 90 crises; and Do these fit a certain mold? Are crises in mature and emerging markets of the same variety? How severe are the consequences of each type of crisis?

4.1. The data

Following the literature on early warnings, this paper will classify currency crises using information on a variety of indicators. These indicators are described in Table 1. They are grouped according to the symptoms on which the various generation models focus. The first-generation models of currency crises highlight the inconsistency of expansionary macroeconomic policies with the stability of a fixed exchange rate regime. Fiscal deficits and easy monetary policy are

[11] The selection of the appropriate threshold that turns the fluctuation in an economic time series into a signal of an upcoming crisis tries to fulfill conflicting criteria. If the threshold is too ''lax'', that is, ''too close'' to normal behavior, it is likely to catch all the crises but it is also likely to catch a lot of crises that never happened, that is, send a lot of false signals. Alternatively, if the threshold is too ''tight'' it is likely to miss all but the most severe of crises – the price of reducing the number of false signals will be reflected in a lower proportion of crises accurately called. The first step of the multiple-regime signals approach, as the first step of the one-regime signals approach, selects the ''optimal'' threshold on an indicator-by-indicator basis by performing a search over all possible thresholds and selecting the value that minimizes the noise-to-signal ratio of each indicator.

[12] Each indicator can be used several times (with different thresholds) to partition the observations. For example, a 40% real appreciation by itself can signal a future crisis. Still, a 10% real appreciation can signal a crisis if accompanied by excessive international borrowing.

Table 1
Indicators of currency crises

Models	Indicators
First generation	Fiscal deficit/GDP Excess real M1 balances
Second generation	Exports Imports Real exchange rate Terms of trade Output Domestic real interest rate
Third generation	Domestic credit/GDP M2/foreign exchange reserves M2 multiplier Bank deposits Stock prices Banking crises
Sovereign debt	Foreign debt/exports Short-term foreign debt/foreign exchange reserves
Sudden stops	World real interest rate Foreign exchange reserves

at the core of these models. I capture the spirit of these models with two indicators: fiscal deficit/GDP and excess M1 real balances.[13] The second-generation models focus on countercyclical government policies. The essence of these models is centered on problems in the current account, with real appreciations fueling losses in competitiveness and recessions. I capture the focus of these models with five indicators: exports, imports, real exchange rate (deviations from equilibrium[14]), terms of trade, output, and real interest rates. The third-generation models focus on financial excesses. To capture the spirit of these models, I use six indicators: domestic credit/GDP ratio, M2/foreign exchange reserves, bank deposits, M2 multiplier, stock prices, and an index of banking crises. The literature on sovereign crises has focused mainly on too much debt and even debt concentrated at short maturities. To examine this variety of crises, I use two indicators: foreign debt/exports, and short-term foreign debt/foreign exchange reserves. Finally, the sudden-stop approach focuses on international capital flow reversals, which I will try to capture with hikes in the world real interest rate and declines of foreign exchange reserves of central banks. There are a total of 18 indicators.[15] The Appendix describes the data in detail.

To examine the characteristics of crises, the paper looks at a total of 20 countries: Argentina, Bolivia, Brazil, Chile, Colombia, Denmark, Finland, Israel, Indonesia, Malaysia, Mexico,

[13] Excess real money balances are the residuals from a money demand equation. Money demand is estimated as a linear function of output and expected inflation.

[14] Not all real appreciations are a signal of losses in competitiveness, with, for example, improvements in productivity in the traded-good sector triggering appreciations in the equilibrium real exchange rate. In this paper ''equilibrium'' movements of the real exchange rate are captured with a time trend. See also Goldfajn and Valdés (1999) for a variety of estimations of the equilibrium real exchange rate and also for linking the various measures of disequilibrium real appreciations to currency crises.

[15] With the exception of the fiscal deficit/GDP, excess real M1 balances, the real exchange rate, and domestic and world real interest rates, all other variables used are in annual growth rates.

Norway, Peru, Philippines, Spain, Sweden, Thailand, Turkey, Uruguay, and Venezuela. As it is conventional in the crisis literature, crisis months are those months with a large exchange rate pressure index.[16] The dates of the crises for the 20 countries are reported in Table 2. Ninety-six crises were identified. I should note that when classifying crises, I do not classify just the month of the crisis. The build-up of fragilities preceding a crisis starts early on. Thus, as in Kaminsky and Reinhart (1999), I define ''crisis episodes'' as the month of the crisis plus the 24 months preceding the crisis. Thus, in the sample, there are 2400 observations of crisis episodes and 7920 observations of tranquil times.[17]

4.2. The classification

To estimate the types of crisis episodes, the data on all indicators for each country are first transformed into percentiles of the distribution. This transformation allows for idiosyncratic factors since, for example, a monthly 20% fall in stock prices can be business as usual in emerging markets but is a strong signal of crisis in a mature economy.

The results of the regression tree are shown in Fig. 1. The hexagons show the various criteria for dividing the sample while the squares are the final groups of observations.[18] The tree algorithm classifies all observations into 18 final groups or nodes. Only nine indicators are used to catalogue all observations: real exchange rates, exports, excess real M1 balances, domestic credit/GDP, M2/foreign exchange reserves, fiscal deficits/GDP, foreign debt/exports, short-term foreign debt/foreign exchange reserves, and world interest rates.[19]

As shown in Fig. 1, the first split of the data is based on the real exchange rate, indicating that real exchange rate appreciations are the most important signal of a forthcoming crisis (with the lowest noise-to-signal ratio of all 18 indicators) and confirming the findings of previous studies (e.g. Goldfajn and Valdés, 1999; Frankel and Rose, 1996). Although not shown, those times with a real exchange rate at the 17.8 percentile of the distribution or lower have a 74.3% probability of crises. In contrast, a more depreciated real exchange rate signals crises with just a 25.7% probability. For those observations with an appreciated real exchange rate, the groups are further defined with classifications based on domestic credit/GDP, fiscal deficit/GDP, world

[16] In the spirit of Eichengreen et al. (1995) and following Kaminsky and Reinhart (1999), the index of currency market turbulence was constructed as a weighted average of exchange rate changes and reserve changes, with weights such that the two components of the index have equal conditional volatilities. Since changes in the exchange rate enter with a positive weight and changes in reserves have a negative weight attached, readings of this index that were three standard deviations or more above the mean were catalogued as crises. With countries in the sample that, at different times, experienced hyperinflation, the construction of the index had to be modified. While a 100% devaluation may be traumatic for a country with low-to-moderate inflation, a devaluation of that magnitude is commonplace during hyperinflations. If a single index for the countries that had hyperinflation episodes were constructed, sizable devaluations and reserve losses in the more moderate inflation periods would be left out since the historic mean is distorted by the high-inflation episode. To avoid this problem, the sample was divided according to whether inflation in the previous 6 months was higher than 150% and then constructed an index for each subsample.

[17] Since the definition of crisis episodes is ad hoc, Kaminsky and Reinhart (1999) check for robustness of the results. In particular, we also define crisis episodes as the 12-month and the 18-month window prior to crises. We find that all qualitative results remain with the different definitions of crisis episodes.

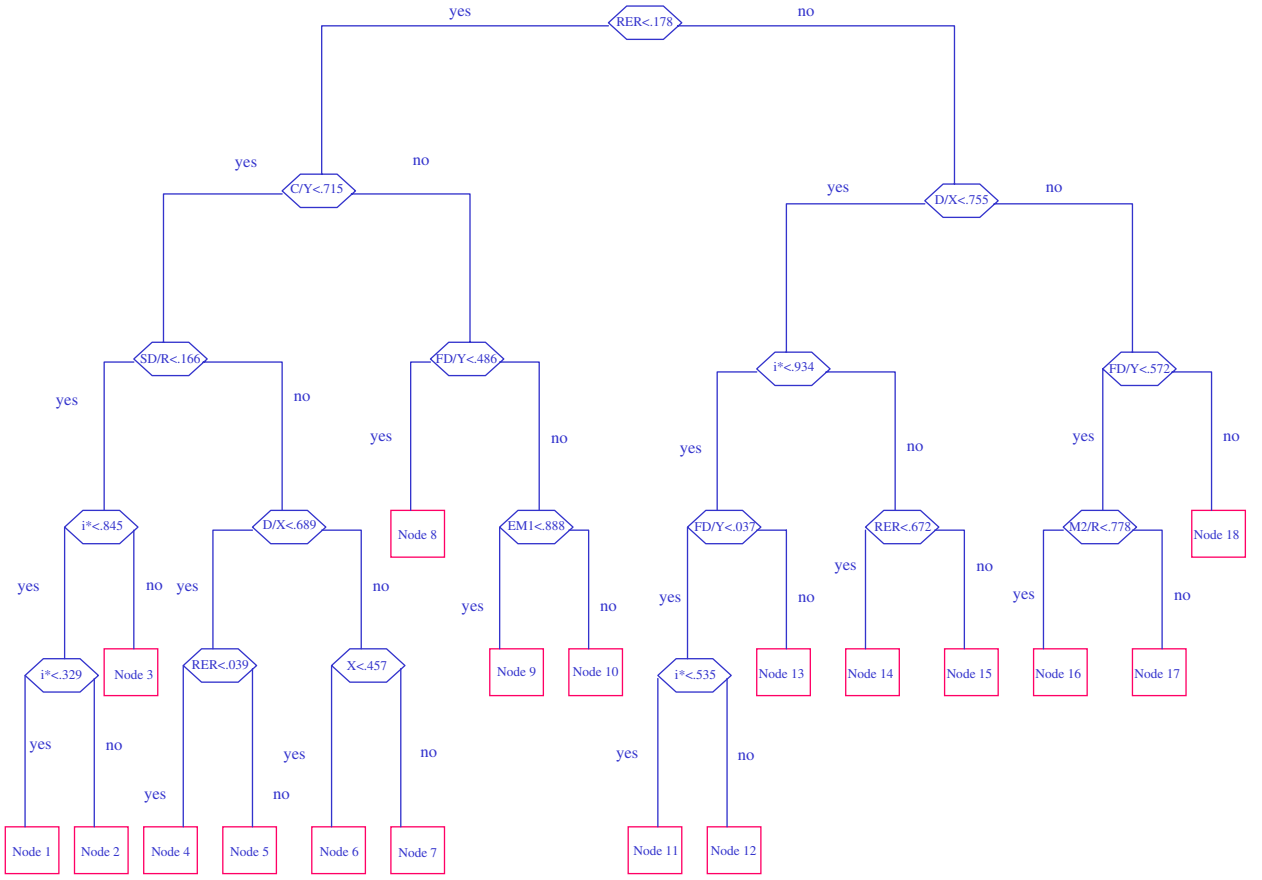
[18] The implicit probabilities of crises can be estimated for both the intermediate and terminal nodes. In the paper, I only show the probabilities associated with the terminal nodes. The probabilities associated with the intermediate nodes are available upon request.

[19] By looking at all the indicators jointly, the regression-tree analysis allows to minimize the number of indicators needed to classify and predict crises. For example, in these estimations, the index of economic activity is not selected as a separate indicator. Economic activity seems to be well captured by some of the chosen indicators, such as the real exchange rate, domestic credit, and fiscal policy.

Table 2
Chronology of currency crises

Country	Currency crisis	Country	Currency crisis
Argentina	June 1970	Malaysia	July 1975
	June 1975		August 1997
	February 1981		June 1998
	July 1982	Mexico	September 1976
	September 1986		February 1982
	April 1989		December 1982
	February 1990		December 1994
	February 2002	Norway	June 1973
Bolivia	November 1982		February 1978
	November 1983		May 1986
	September 1985		December 1992
Brazil	February 1983		July 1998
	November 1986		July 1999
	July 1989		November 2000
	November 1990	Peru	June 1976
	October 1991		October 1987
	January 1999		September 1988
Chile	December 1971	Philippines	February 1970
	August 1972		October 1983
	October 1973		June 1984
	December 1974		February 1986
	January 1976		December 1997
	August 1982	Spain	February 1976
	September 1984		July 1977
Colombia	March 1983		December 1982
	February 1985		September 1992
	August 1995		May 1993
	September 1997	Sweden	August 1977
	September 1998		September 1981
	August 1999		October 1982
Denmark	May 1971		November 1992
	June 1973	Thailand	November 1978
	November 1979		July 1981
	August 1993		November 1984
Finland	June 1973		July 1997
	October 1982		January 1998
	November 1991		September 1999
	September 1992		July 2000
Indonesia	November 1978	Turkey	August 1970
	April 1983		January 1980
	September 1986		March 1994
	December 1997		February 2001
	January 1998	Uruguay	December 1971
Israel	November 1974		October 1982
	November 1977	Venezuela	February 1984
	October 1983		December 1986
	July 1984		March 1989
			May 1994
			December 1995

Sources: Kaminsky and Reinhart (1999) and updates.



Notation: RER= real exchange rate, C/Y= Domestic Credit/GDP, i*=World Interest Rate, EM1= Excess Real M1 Balances, FD/Y= Fiscal Deficit/GDP, M2/R=M2/Reserves, SD/R= Short-term Debt/Reserves, X=Exports, D/X= Debt/X

Fig. 1.

interest rates, foreign debt/exports, short-term foreign debt/foreign exchange reserves, and excess M1 real balances. In particular, some observations (node 10) are identified by real appreciations, high domestic credit/GDP, and high excess M1 real balances. Those observations are associated with an 82.9% probability of crises. Similarly, for those observations (in the initial split) with no problems of real appreciation (observations with real exchange rates higher than the 17.8 percentile), the groups are further defined with classifications based on the level of world interest rates, fiscal deficits/GDP, and M2/foreign exchange reserves ratio. In particular, one variety of crises identified in this branch is the one studied by the first-generation models. The observations in this group (node 11) are just characterized by fiscal problems (fiscal deficits/GDP in the 3.7 percentile or lower) and are associated with an 87% probability of crises.[20]

Table 3 describes in detail the characteristics of the final groups. The indicators signaling vulnerability are shown in bold. For example, the first node is characterized by a real appreciation of the domestic currency (real exchange rate in the 17.8 percentile or lower), low domestic credit/GDP ratio (domestic Credit/GDP in the 71.5 percentile or lower), low short-term foreign debt/foreign exchange reserves (short-term foreign debt/foreign exchange reserves in the 16.6 percentile or lower), and low world interest rates (world interest rates in the 32.9 percentile or lower). Thus, the only observed vulnerability in this group is the appreciation of the real exchange rate, which is shown in bold characters.

While the tree-regression estimation classifies all observations into 18 distinct groups, in reality several of these groups share quite similar traits, suggesting that these groups are just manifestations of only one type of currency crises. For example, the vulnerabilities in groups 1 and 2 are only related to the real appreciation of the domestic currency while the vulnerabilities of groups 14 and 15 are just associated with hikes in world interest rates. To account for these similarities, I combine the 18 groups into six varieties of crises. Ten of those groups/nodes are characterized by episodes of real appreciation. For four of them, real appreciations reflect the only shown vulnerability. I catalogue these groups as *Crises with Current Account Problems*.[21] For the other six, a real appreciation is not necessarily the only trigger of crises; it just contributes to the build-up of economic fragilities. When the fragilities are associated with booms in financial markets (as in nodes 8, 9 and 10), crises are catalogued as *Crises of Financial Excesses*.[22] In particular, they are identified as crises that are preceded by the acceleration in the growth rate of domestic credit and other monetary aggregates. In turn, when the fragilities are associated with ''unsustainable'' foreign debt (as in nodes 6, 7, 16, 17 and 18), crises are classified as *Crises of Sovereign Debt Problems*. The fourth variety of crises is related to expansionary fiscal policy (nodes 11 and 12). These crises are labeled *Crises with Fiscal Deficits*.[23] *Sudden-stop Crises* constitute the fifth variety of crises. This type of crisis is associated with reversals in capital flows triggered by hikes in world interest rates (nodes 3, 14 and 15).[24] Finally, *Self-fulfilling Crises*

[20] Since fiscal deficits are represented with negative numbers, large fiscal deficits are located in the left tail of the distribution.

[21] These crises can also be associated with the second-generation models of currency crises.

[22] See also Gourinchas et al. (2001) and Schneider and Tornell (2004) for an analysis of the relationship between booms and busts in credit markets and crises.

[23] These crises can also be associated with the first-generation models of currency crises.

[24] Guillermo Calvo (1998) introduced the concept of sudden stops in the crisis literature. Sudden stops in this interpretation are associated with a reversal of international capital flows. But hikes in world interest rates or changes in international investors' sentiments are not the only defining characteristic of sudden-stop crises. These crises are also linked to vulnerabilities in borrower countries, which include high levels of debt, dollarization, and debt concentrated at very short maturities. In our classification, sudden-stop crises are just associated to one type of vulnerability: severe hikes in world interest rates.

Table 3
Varieties of currency crises

Outcomes	Characteristics	Current account	Financial excesses	Fiscal deficit	Sovereign debt	Sudden stops	Self-fulfilling	Probability of currency crises
1	**Real appreciation < 0.178** Low domestic credit/GDP growth < 0.715 Low short-term foreign debt/reserves < 0.166 Low world interest rate $i^* < 0.329$	*						66.3
2	**Real appreciation < 0.178** Low domestic credit/GDP growth < 0.715 Low short-term foreign debt/reserves < 0.166 0.329 < Moderate world interest rate < 0.845	*						6.3
3	**Real appreciation < 0.178** Low domestic credit/GDP growth < 0.715 Low short-term foreign debt/reserves < 0.166 **High world interest rate > 0.845**					*		93.2
4	**Extreme real appreciation < 0.039** Low domestic credit/GDP growth < 0.715 Moderate short-term foreign debt/reserves > 0.166 Low foreign debt/exports < 0.689	*						62.8
5	**0.039 < Real appreciation < 0.178** Low domestic credit/GDP growth < 0.715 Moderate short-term foreign debt/reserves > 0.166 Low foreign debt/exports < 0.689	*						30.1
6	**Real appreciation < 0.178** Low domestic credit/GDP growth < 0.715 **Moderate short-term foreign debt/reserves > 0.166** **High foreign debt/exports > 0.689** **Deteriorating exports < 0.457**				*			72.8
7	**Real appreciation < 0.178** Low domestic credit/GDP growth < 0.715 **Moderate short-term foreign debt/reserves > 0.166** **High foreign debt/exports > 0.689** Growing exports > 0.457				*			35.9

8	**Real appreciation < 0.178** **High domestic credit/GDP growth > 0.715** **High fiscal deficit < 0.486**	*				87.4
9	**Real appreciation < 0.178** **High domestic credit/GDP growth > 0.715** Low fiscal deficit > 0.486 Contractionary monetary policy < 0.888	*				13
10	**Real appreciation < 0.178** **High domestic credit/GDP growth > 0.715** Low fiscal deficit > 0.486 **Expansionary monetary policy > 0.888**	*				82.9
11	Real depreciation > 0.178 Low foreign debt/exports < 0.755 Low world interest rate i^* < 0.535 **Extremely high fiscal deficit < 0.037**		*			87
12	Real depreciation > 0.178 Low foreign debt/exports < 0.755 0.535 < Moderate world interest rate i^* < 0.934 **Extremely high fiscal deficit < 0.037**		*			14.3
13	Real depreciation > 0.178 Low foreign debt/exports < 0.755 Low world interest rate i^* < 0.934 No extremely high fiscal deficit > 0.037				*	13.5
14	0.178 < Moderate real appreciation < 0.672 Low foreign debt/exports < 0.755 **Extremely high world interest rate i^* > 0.934**			*		56
15	Real depreciation > 0.672 Low foreign debt/exports < 0.755 **Extremely high world interest rate i^* > 0.934**			*		9.2
16	Real depreciation > 0.178 **High foreign debt/exports > 0.755** Moderate fiscal deficit < 0.572 Low M2/reserves < 0.778		*			34.9

(*continued on next page*)

Table 3 (*continued*)

Outcomes	Characteristics	Current account	Financial excesses	Fiscal deficit	Sovereign debt	Sudden stops	Self-fulfilling	Probability of currency crises
17	Real depreciation > 0.178 **High debt/exports > 0.755** Moderate fiscal deficit < 0.572 **High M2/reserves > 0.778**				*			68.7
18	Real depreciation > 0.178 **High debt/exports > 0.755** Moderate fiscal deficit < 0.572				*			19.6

Notes: The * indicates to which variety of crises each group belongs.

are those associated with node 13, which does not exhibit any evident vulnerability. The last column of Table 3 shows the associated probabilities of crises of each node.

4.3. Varieties of crises in emerging and mature economies

Table 4 shows the classification of the ninety-six crises in the sample into the six varieties on a crisis-by-crisis basis.[25] To classify each crisis, I look at the episode of crisis (the month of the crisis and the 24 preceding months) and compute the number of months in the crisis episode classified in each of the terminal nodes. Then, using the classification of crisis in Table 3, I tally the number of months in that particular episode with vulnerabilities arising from the current account, financial excesses, fiscal deficits, debt problems, or sudden stops. For example, for the February 1981 crisis in Argentina, there were signs of booms in financial markets in 11 months of the episode, there were signs of overvaluation of the domestic currency in 1 month of the episode, while there were no signs of vulnerability in the remaining 13 months of the crisis episode. Many of the crisis episodes only reflect one type of vulnerability, be it current account problems, financial excess, fiscal problems, debt problems or sudden stops. In this case, the classification of the crisis is straightforward; the crisis is classified in one of those five varieties. Similarly, some crises are not preceded by any type of vulnerability (all the 25 observations in a crisis episode are classified in outcome 13). In this case, the episode is classified as a self-fulfilling crisis, the sixth variety of crises. But other crises are preceded by signs of various types of vulnerabilities. In this case, as a general rule, a crisis is classified as type *j* if the majority of the months of the crisis episode are classified in variety *j*. So, for example, as shown in Table 4, the collapse of the Turkish Lira in February 2001 is classified as a crisis of financial excesses because there are 22 months classified in outcomes 8 and 10 (with signs of booming financial markets) and just 2 months with signs of debt problems.[26] The last column of the table shows the classification of each crisis.

For all the countries, this classification indicates that 14% of the crises are related to current account problems, 29% are crises of financial excesses, 5% are crises with fiscal problems, 42% are crises of sovereign debt problems, 5% of the crises are related to sudden stops, and just 4% of the crises are self-fulfilling crises.

Table 5 shows the varieties of crises in emerging and mature economies.[27] As shown in this table, crises in emerging markets tend to be of a different variety than those in mature markets.

[25] For three of these crises, there is no data available on the various indicators. So, only 93 crises are classified.

[26] There are three exceptions to the general rule. First, a number of crisis episodes include some observations classified as observations with current account problems and some other observations classified as observations with financial excesses. Since crises of financial excesses are characterized by excessive expansion of credit/monetary aggregates as well as by real appreciations as in the case of crises with current account problems, I classify those crisis episodes as episodes with financial excesses to show the presence of multiple vulnerabilities. For example, current account problems and financial excesses were widespread during the Mexican crisis of December 1994, with 14 months showing current account problems and 9 months showing ''financial excesses''. The 1994 Mexican crisis is classified as a crisis of financial excesses even though the number of months with current account problems exceeds that with financial excesses. Second, some crisis episodes include observations with debt problems and fiscal problems. Since fiscal problems are part and parcel of debt problems, those crisis episodes are classified as crises with debt problems. Third, some crisis episodes include observations with financial excesses and observations with debt problems. Again, as debt problems are part and parcel of financial excesses, those episodes are classified as crises of financial excesses. A final note, when observations are classified into various groups, the only groups that are considered for the classification of the crisis episode are those that include at least six observations. Since this is an ad-hoc criterion, robustness tests have been performed. Qualitative results are not affected. The results are available upon request.

[27] Denmark, Finland, Norway, Spain, and Sweden are the mature economies in the sample. The remaining countries in the sample are considered emerging economies.

Table 4
Classification of crisis episodes

Country	Crisis	Months of crises with problems of					Variety
		Current account	Financial excesses	Fiscal deficits	Sovereign debt	Sudden stops	
Argentina	Jun 1970	–	–	–	–	–	n.a.
	Jun 1975	6	15	0	2	0	Financial excesses
	Feb 1981	1	11	0	0	0	Financial excesses
	Jul 1982	4	7	0	2	11	Financial excesses
	Sep 1986	0	0	0	21	0	Sovereign debt
	Apr 1989	0	0	0	23	0	Sovereign debt
	Feb 1990	0	0	0	19	0	Sovereign debt
	Jan 2002	7	3	0	0	0	Current account
Bolivia	Nov 1982	5	8	0	3	8	Financial excesses
	Nov 1983	4	8	0	4	4	Financial excesses
	Sep 1985	2	0	0	4	18	Sudden stops
Brazil	Feb 1983	0	0	0	11	11	Sovereign debt
	Nov 1986	0	0	0	24	0	Sovereign debt
	Jul 1989	0	0	0	8	0	Sovereign debt
	Nov 1990	0	0	4	7	0	Sovereign debt
	Oct 1991	0	0	1	3	0	Sovereign debt
	Jan 1999	11	12	0	2	0	Financial excesses
Chile	Dec 1971	0	0	0	5	0	Sovereign debt
	Aug 1972	0	0	6	7	0	Sovereign debt
	Oct 1973	8	0	10	3	0	Fiscal deficits
	Dec 1974	8	0	2	0	0	Current account
	Jan 1976	0	0	0	7	0	Sovereign debt
	Aug 1982	0	0	0	7	9	Sovereign debt
	Sep 1984	0	0	0	24	0	Sovereign debt
Colombia	Mar 1983	1	12	0	10	1	Financial excesses
	Feb 1985	0	6	0	16	0	Financial excesses
	Aug 1995	0	1	0	0	0	Financial excesses
	Sep 1997	11	2	0	2	0	Current account
	Sep 1998	9	12	0	3	0	Financial excesses
	Aug 1999	3	16	1	5	0	Financial excesses
Denmark	May 1971	0	0	0	0	0	Self-fulfilling
	Jun 1973	0	0	0	0	0	Self-fulfilling
	Nov 1979	19	0	0	0	0	Current account
	Aug 1993	0	0	0	11	0	Sovereign debt
Finland	Jun 1973	0	0	0	0	0	Self-fulfilling
	Oct 1982	0	0	0	0	22	Sudden stops
	Nov 1991	1	5	0	21	0	Sovereign debt
	Sep 1992	0	3	0	20	0	Sovereign debt
Indonesia	Nov 1978	8	0	2	2	0	Current account
	Apr 1983	0	15	0	0	9	Financial excesses
	Sep 1986	2	0	0	4	3	Sovereign debt
	Dec 1997	0	0	0	14	0	Sovereign debt
	Jan 1998	0	0	0	18	0	Sovereign debt

Table 4 (*continued*)

Country	Crisis	Months of crises with problems of					Variety
		Current account	Financial excesses	Fiscal deficits	Sovereign debt	Sudden stops	
Israel	Nov 1974	7	5	0	1	0	Current account
	Nov 1977	4	13	0	0	0	Financial excesses
	Oct 1983	0	0	0	23	2	Sovereign debt
	Jul 1984	0	0	0	25	0	Sovereign debt
Malaysia	Jul 1975	12	5	0	1	0	Current account
	Aug 1997	0	12	0	1	0	Financial excesses
	Jun 1998	0	10	0	3	0	Financial excesses
Mexico	Sep 1976	0	1	0	2	0	Sovereign debt
	Feb 1982	4	5	0	3	3	Financial excesses
	Dec 1982	4	5	0	7	5	Sovereign debt
	Dec 1994	15	9	0	0	0	Financial excesses
Norway	Jun 1973	0	0	0	0	0	Self-fulfilling
	Feb 1978	6	17	0	2	0	Financial excesses
	May 1986	0	0	0	2	3	Sudden stops
	Dec 1992	0	0	12	5	0	Fiscal deficits
	Jan 1998	0	0	0	2	0	Sovereign debt
	Jul 1999	0	0	0	18	0	Sovereign debt
	Nov 2000	0	0	0	12	0	Sovereign debt
Peru	Jun 1976	12	4	0	3	0	Current account
	Oct 1987	0	0	0	23	0	Sovereign debt
	Sep 1988	0	0	0	19	0	Sovereign debt
Philippines	Feb 1970	–	–	–	–	–	n.a.
	Oct 1983	1	13	0	7	2	Financial excesses
	Jun 1984	0	8	0	15	0	Financial excesses
	Feb 1986	0	2	0	22	0	Sovereign debt
	Dec 1997	0	20	0	0	0	Sovereign debt
Spain	Feb 1976	4	1	0	0	0	Current account
	Jul 1977	10	0	0	0	0	Current account
	Dec 1982	0	0	0	7	16	Sovereign debt
	Sep 1992	12	12	0	0	0	Financial excesses
	May 1993	9	7	0	1	0	Financial excesses
Sweden	Aug 1977	24	0	0	0	0	Current account
	Sep 1981	0	0	0	0	10	Sudden stops
	Oct 1982	0	0	0	0	22	Sudden stops
	Nov 1992	8	0	0	16	0	Sovereign debt
Thailand	Nov 1978	4	0	0	0	0	Current account
	Jul 1981	3	1	0	0	3	Current account
	Nov 1984	1	23	0	1	0	Financial excesses
	Jul 1997	1	2	0	20	0	Sovereign debt
	Jan 1998	0	2	0	21	0	Sovereign debt
	Sep 1999	0	0	8	14	0	Sovereign debt
	Jul 2000	0	0	11	4	0	Fiscal deficits

(*continued on next page*)

Table 4 (*continued*)

Country	Crisis	Months of crises with problems of					Variety
		Current account	Financial excesses	Fiscal deficits	Sovereign debt	Sudden stops	
Turkey	Aug 1970	–	–	–	–	–	n.a.
	Jan 1980	6	0	0	9	0	Sovereign debt
	Mar 1994	2	0	0	14	0	Sovereign debt
	Feb 2001	0	22	0	2	0	Financial excesses
Uruguay	Dec 1971	0	0	0	4	0	Sovereign debt
	Oct 1982	5	16	0	8	0	Financial excesses
Venezuela	Feb 1984	2	6	0	4	8	Financial excesses
	Dec 1986	0	0	0	20	1	Sovereign debt
	Mar 1989	0	0	0	25	0	Sovereign debt
	May 1994	0	0	5	1	0	Fiscal deficits
	Dec 1995	3	0	11	0	0	Fiscal deficits

Note: Crisis episodes include the month of the crisis and the 24 months prior to the crisis.

For example, current account and competitiveness problems are more of a trait of mature markets (17% of the crises) than of emerging economies (13% of the crises). While it is true that losses of competitiveness also affect emerging economies, lack of competitiveness is just one of the multiple vulnerabilities found in these economies at the onset of crises. More often than not, lack of competitiveness is accompanied by highly expansionary credit growth and loose monetary policy or debt problems or even macro-policies inconsistent with the stability of the peg. Overall, 86% of the crises in emerging economies are crises with multiple domestic vulnerabilities while economic fragility only characterizes 50% of the crises in mature markets.[28] Sudden-stop problems are also more common in mature markets (17% of all crises) than in emerging markets (2% of all crises). Again, in our classification, sudden-stop problems are just characterized by adverse shocks to international capital markets and crises in emerging economies mostly occur in the midst of multiple vulnerabilities. Finally, while most of the crises are preceded by real, financial, or external fragilities, a small number of crises are unrelated to deteriorating fundamentals (self-fulfilling crises). These crises are not a feature of emerging markets but tend to occur in mature markets.[29]

Table 6 evaluates the costs of the different varieties of crises. Costs are grouped into three categories. The first one captures the magnitude of the speculative attack. Two indicators are used: losses of reserves and real exchange rate depreciations. For reserves, I use the 6-month percentage change prior to the month of the crisis, as losses of reserves tend to occur before the devaluation occurs (if the speculative attack is successful). For the real exchange rate depreciation, I use the 6-month percentage real depreciation following the month of the crisis

[28] The crises associated with multiple vulnerabilities are Crises of Financial Excesses, Crises of Fiscal Deficits, and Crises of Sovereign Debt problems.

[29] While in the theoretical literature self-fulfilling crises are associated with the EMS crises in 1992 and 1993, the implied classification from the regression tree identifies those episodes as crises with domestic vulnerabilities. In the case of Denmark, Finland, Norway, and Sweden, vulnerabilities are associated with international borrowing and debt problems, while in the case of Spain, fragilities are related to financial excesses. The regression tree only classifies as self-fulfilling crises, or crises with immaculate fundamentals, the crises associated with the collapse of the Bretton Woods System.

Table 5
Crises in emerging and mature markets

Countries	Number of crises (in percent)					
	Current account	Financial excesses	Fiscal deficits	Sovereign debt	Sudden stops	Self-fulfilling
Emerging	13	35	6	45	2	0
Mature	17	13	4	33	17	17

Ratio	Relative importance of crises in the two regions					
	Current account	Financial excesses	Fiscal deficits	Sovereign debt	Sudden stops	Self-fulfilling
E/M	0.8	2.7	1.5	1.4	0.1	0

Notes: The top panel shows the percent of crises in each variety. For example, 35% of all crises in emerging markets are classified as crises of financial excesses. The bottom panel shows the ratio of the number of crises in emerging countries/the number of crises in mature countries.

since large devaluations tend to occur only after and if the central bank concedes by devaluing or floating the currency. The second category focuses on output losses (relative to trend) in the year of the crisis and 1 year after the crisis so as to examine not only the magnitude of the collapse following the crisis but also the persistence of output losses. The third category looks at access to international capital markets in the aftermath of the crisis. It focuses on the behavior of the trade account in the year following the crisis. The table reports separately the 12-month percentage change (relative to trend) in exports and imports following the month of the crisis. The first six columns report the average for each variety of crises. The last column shows the average across all crises.

As shown in Table 6, reserve losses oscillate around 14% for all crises with the exception of those classified as self-fulfilling, for which reserves increase about 15% in the months preceding the crises. The depreciation of the real exchange rate across type of crises

Table 6
Varieties and costs of crises

Indicator	Costs of crises (in percent)						
	Current account	Financial excesses	Fiscal deficits	Sovereign debt	Sudden stops	Self-fulfilling	All crises (average)
Reserve losses	−14.1	−13.0	−19.6	−12.7	−12.5	15.4	−12.1
Depreciation	15.1	30.8**	24.3	20.1	13.3	1.2*	20.1
Growth t	−1.9	−3.8*	−1.9	−3.4	−0.2*	0.6**	−2.9
Growth $t+1$	−0.9	−0.7	−2.8*	−0.3	−0.3	−0.4	−0.7
Imports growth	−3.9	−24.5**	7.2	−4.8	−6.0	22.4	−8.2
Exports growth	4.3	−0.5	−7.6	0.4	5.3	19.5*	1.3

Notes: Reserve losses are computed as the change in foreign exchange reserves of the central bank in the 6 months prior to the crisis. Depreciation is computed as the real exchange rate depreciation in the 6 months after the crisis. Growth in the aftermath of crises is computed as the changes in output relative to mean growth during the sample. t and $t+1$ refer to the year of the crisis and the year following the crisis, respectively. Import (export) growth is computed as the change in imports (exports) − relative to trend − in the 12 months following the crisis.
*, **, *** refer to 10%, 5%, and 1% significance values. The null hypothesis is that the severity of the particular variety of crises is equal to that of the average crisis. The significance values refer to one-tail tests and reflect the alternative hypothesis that the cost of a particular type of crisis is larger (smaller) than that of the average crisis.

is more varied and oscillates between 1% and 31%. Depreciations are most extreme in the case of crises of financial excesses. As is the case with real depreciations, output losses (relative to trend) are also substantially larger in the aftermath of crises of financial excesses. In this case, output losses increase to almost 4%. In contrast, output (relative to trend) is unchanged or continues to grow in the aftermath of crises with no observed domestic fragility, both those of the sudden-stop and the self-fulfilling varieties. Output losses are somewhat persistent. On average, in the year following the crisis, output continues to fall relative to trend. Again, declines in economic activity are less pronounced in the aftermath of crises with no domestic fragility.

Finally, Table 6 also shows that, as discussed in Calvo (1998) and Calvo and Reinhart (2000), access to international capital markets can be severely impaired in the aftermath of crises, with countries having to run sizable current account surpluses to repay their debt. The size and type of the adjustment vary across types of crises. For example, in the case of crises with financial excesses, most of the adjustment occurs on the import side, with imports falling − relative to trend − approximately 25%. In contrast, exports fail to grow (deviations from trend growth are almost 0) even though the depreciations during this type of crises are massive. This evidence suggests that countries are even unable to attract trade credits to finance exports when their economies are mired in financial problems.[30] In contrast, for crises with no domestic fragilities, booming exports are at the heart of the recovery of the current account. Summarizing, on average, the costs of crises with financial excesses are significantly higher than those of other crises, with crises of debt problems being a close second. On the opposite end, self-fulfilling crises or crises triggered by just reversal in capital flows have no noticeable adverse effects on the economy.

5. The early warnings

Fig. 2 reports the time-series probabilities of currency crises implicit in the estimation for all countries in the sample for the period January 1970–December 2001. The shaded areas in the figures are ''crisis times''. Overall, there are 2400 observations of crises (30%) and 7920 observations of ''tranquil times'' (70%). Macroeconomic vulnerabilities are basically not present during ''tranquil times'', with 77% of the observations being classified under outcome 13. For those observations, the probability of crises is just 13.5%. This is the frequency of crises in times of immaculate fundamentals.

In most cases, vulnerabilities are highly persistent and they trigger repeated exchange rate crises. For example, Colombia suffered a series of crises in the late 1990s. Similarly, the July 1997 crisis in Thailand that set the onset of the Asian crisis was followed by a string of crises that only ended in July 2000. Episodes of multiple crises can be of the same nature. This was the case of Argentina in the late 1980s and beginning of the 1990s, with debt problems at the heart of all speculative attacks. In contrast, the nature of the crises in Thailand evolved from problems of excessive borrowing at the beginning of the episode to fiscal problems following the bailout of the banking sector.

This section evaluates the forecasting accuracy of the multiple-regime signals approach vis-à-vis the traditional signals approach (Kaminsky, 1998). I follow Diebold and Rudebusch

[30] See Corsetti et al. (1999) for a chronology of the Asian crisis in 1997–1998 with an emphasis on financial over-lending before the crisis and the liquidity crunch following the devaluations. See also Mishkin (1996) for an analysis of over-lending cycles in emerging markets.

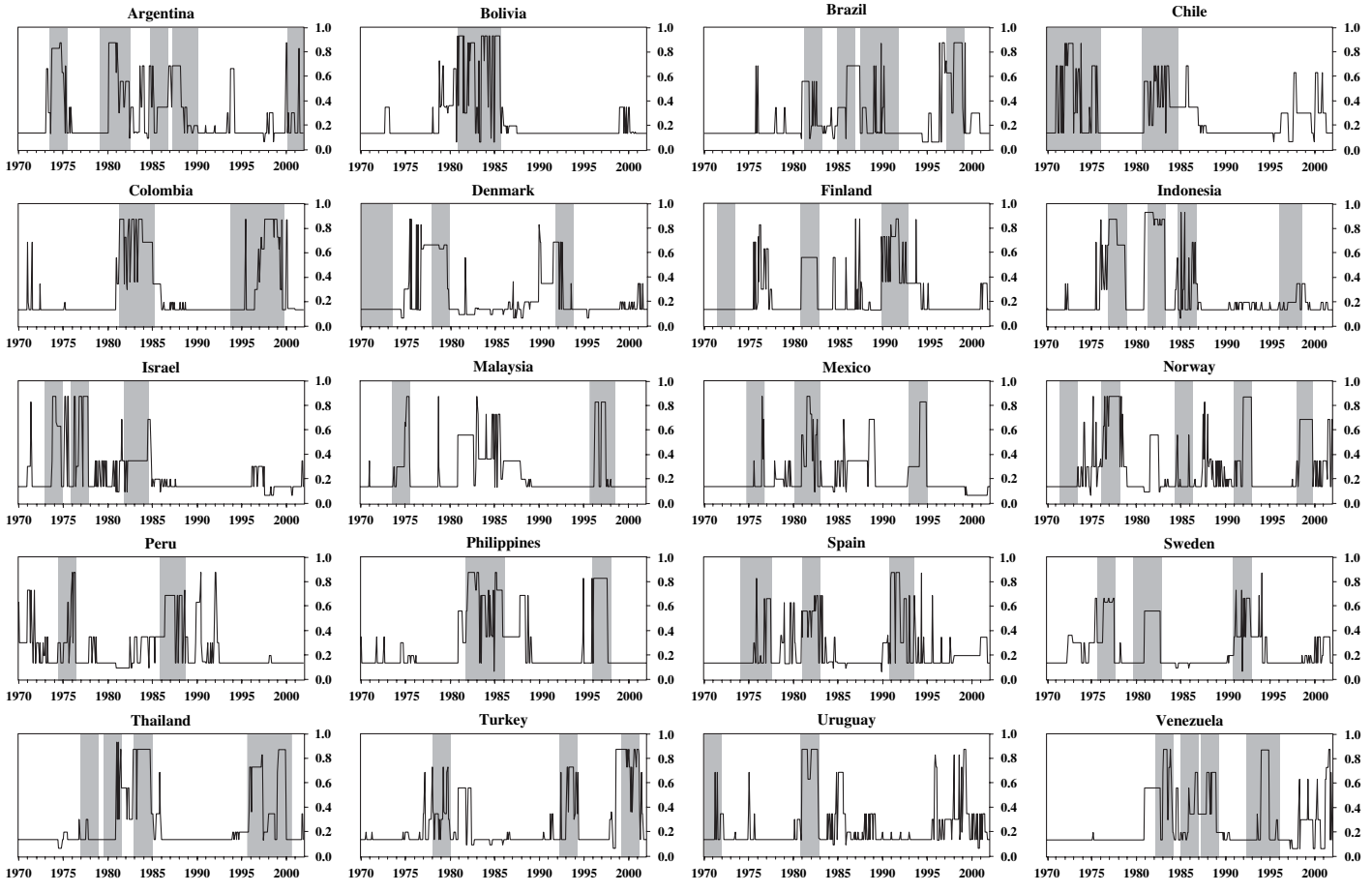


Fig. 2. Probabilities of currency crises.

(1989) in evaluating both techniques. Two tests are implemented to evaluate the average closeness of the predicted probabilities and observed realizations, as measured by a 0–1 dummy variable. Suppose we have T probability forecasts:

$$\left\{P_t^k\right\}_{t+1}^{T} \tag{1}$$

where P_t^k is the probability of crisis conditional on information provided by the indicator k in period t. Similarly, let

$$\{R_t\}_{t+1}^{T} \tag{2}$$

be the corresponding time series of realizations; R_t equals 1 during crisis episodes and 0 otherwise. The first scoring-rule is the quadratic probability score, (QPS), given by

$$\mathrm{QPS}^k = \frac{1}{T}\sum_{t=1}^{T} 2\left(P_t^k - R_t\right)^2 \tag{3}$$

The QPS ranges from 0 to 2, with a score of 0 corresponding to perfect accuracy.

The second scoring-rule is the log probability score (LPS), given by

$$\mathrm{LPS}^k = -\frac{1}{T}\sum_{t=1}^{T}\left[(1-R_t)\ln\left(1-P_t^k\right) + R_t\ln\left(P_t^k\right)\right] \tag{4}$$

The LPS ranges from 0 to ∞, with a score of 0 corresponding to perfect accuracy. The loss function associated with LPS differs from that corresponding to QPS, as large mistakes are penalized more heavily under LPS.

Table 7 shows both the Quadratic Probability Score (QPS) and the log Probability Score (LPS) for the forecasting probabilities of the two indicators. The score statistics are reported separately for the whole sample, ''Crisis Times'' and ''Tranquil Times''. As shown in this table, the multiple-regime signals approach makes a substantial improvement over the traditional signals approach. This holds regardless of the loss function used. For the whole sample, the losses in forecasting accuracy from using the one-regime signals approach reach 26%. Losses in predictive accuracy from using the one-regime signals approach even reach 47% during tranquil times, indicating that the multiple-regime signals approach issues substantially less false alarms.

Table 7
Forecasting accuracy

Episodes	Forecasting accuracy of signals approach			
	One regime		Multiple regime	
	QPS	LPS	QPS	LPS
All sample	0.369	0.561	0.293	0.464
Crisis times	0.937	1.249	0.779	1.069
Tranquil times	0.161	0.308	0.109	0.235

Notes: QPS refers to the quadratic probability score and LPS refers to the log probability score.

6. Conclusions

Currency crises are not a new phenomenon. Not only is the list of countries affected by these crises long but it is also increasing. Many have emphasized the destructive forces of currency crises, and the economics profession as a whole is crusading to find ways of avoiding crises. But while some countries collapse following a crisis, many others that also fall prey to speculative attacks do not suffer catastrophic consequences, suggesting that crises come in many varieties. Yet, most previous empirical studies of crises have failed to allow for this diversity.

In this paper, I used regression-tree methods to classify 96 crises in 20 countries from 1970 to 2001. The results indicate that crises are not created equal, with the empirical classification reflecting the varieties proposed by the various generations of models of currency crises. Still, some models are better than others at capturing the stylized characteristics of crises. For example, I find that most of the crises are characterized by multitude of weak economic fundamentals, suggesting that it would be difficult to characterize them as ''self-fulfilling'' crises.

Finally, since crises are of different varieties, early-warning systems should allow for multiple regimes. Thus, the second-generation early-warning systems should incorporate methodologies such as regression-tree analysis or parametric multiple-regime models à la Hamilton (1989) to capture a broad spectrum of crises.

Data appendix. The indicators: sources and definitions

Sources: *International Financial Statistics* (IFS), International Monetary Fund (IMF); *Emerging Market Indicators*, International Finance Corporation (IFC); *World Development Indicators*, The World Bank (WB); *The Maturity, Sectoral, and Nationality Distribution of International Bank Lending*, Bank for International Settlements (BIS); *International Banking and Financial Market Developments*, Bank for International Settlements. When data were missing from these sources, central bank bulletins and other country-specific sources were used as supplements. Unless otherwise noted, all variables are in 12-month percent changes.

1. *M2 multiplier*: The ratio of M2 (IFS lines 34 plus 35) to base money (IFS line 14).
2. *Domestic credit/GDP*: IFS line 52 divided by IFS line 64 to obtain domestic credit in real terms, which was then divided by IFS line 99b.p. (interpolated) to obtain the domestic credit/GDP ratio. Monthly real GDP was interpolated from annual data.
3. *Domestic real interest rate*: Deposit rate (IFS line 60) deflated using consumer prices (IFS line 64). Monthly rates expressed in percentage points. In levels.
4. *''Excess'' Ml balances*: Ml (IFS line 34) deflated by consumer prices (IFS line 64) less an estimated demand for money. The demand for real balances is determined by real GDP (interpolated IFS line 99b.p.), domestic consumer price inflation, and a time trend. Domestic inflation was used in lieu of nominal interest rates, as market-determined interest rates were not available during the entire sample for a number of countries; the time trend is motivated by its role as a proxy for financial innovation and/or currency substitution. In levels.
5. *M2/foreign exchange reserves*: IFS lines 34 plus 35 converted into dollars (using IFS line ae) divided by IFS line IL.d.
6. *Bank deposits*: IFS lines 24 plus 25 deflated by consumer prices (IFS line 64).
7. *Exports*: IFS line 70.
8. *Imports*: IFS line 71.

9. *Terms of trade*: The unit value of exports (IFS line 74) over the unit value of imports (IFS line 75). For those developing countries where import unit values (or import price indices) were not available, an index of prices of manufactured exports from industrial countries to developing countries was used.
10. *The real exchange rate*: The real exchange rate index is derived from a nominal exchange rate index, adjusted for relative consumer prices (IFS line 64). The measure is defined as the relative price of foreign goods (in domestic currency) to the price of domestic goods. The real exchange rate index of a country is a weighted average of the real exchange rates vis-à-vis 19 OECD countries with weights equal to the country trade shares with the OECD countries. Since not all real appreciations reflect disequilibrium phenomena, we focus on deviations of the real exchange rate from trend. In levels.
11. *Foreign exchange reserves*: IFS line IL.d.
12. *Output*: For most countries, the measure of output used is industrial production (IFS line 66). However, for some countries (the commodity exporters), an index of output of primary commodities is used (IFS lines 66aa) if industrial production is not available.
13. *Stock prices*: IFC global indices are used for all emerging markets: for industrial countries the quotes from the main boards are used. All stock prices are in US dollars.
14. *Short-term foreign debt/foreign exchange reserves*: Liabilities of domestic residents to BIS reporting banks with maturities up to 1 year (*The Maturity, Sectoral, and Nationality Distribution of International Bank Lending*, Bank for International Settlements) divided by IFS line 1L.d.
15. *Foreign debt/exports*: Liabilities of domestic residents to BIS reporting banks (*International Banking and Financial Market Developments* (BIS)) divided by IFS line 70.
16. *World real interest rate*: US deposit rate (IFS line 60) deflated using consumer prices (IFS line 64). Monthly rates expressed in percentage points. In levels.
17. *Fiscal deficit/GDP*: The ratio of fiscal deficit (IFS line 80) deflated by consumer prices (IFS line 64) to GDP (IFS line 99b.p.) interpolated.
18. *Banking crises*: Index of banking crises from Kaminsky and Reinhart (1999) (updated to 2002).

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