# Methodology for an Early Warning System: The Signals Approach

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# Methodology for an Early Warning System: The Signals Approach

***Assessing Financial Vulnerability: An Early Warning System for Emerging Markets***

*Notes from Chapter 2*

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. *In this chapter we provide a brief review of the "signals" approach used in this book to assess the probability of a currency or a banking crisis. This methodology was first used to analyze the performance of a variety of macroeconomic and financial indicators around the "twin crises" in Kaminsky and Reinhart (1996) and is described in greater detail in Kaminsky, Lizondo, and Reinhart (1998). In the analysis that follows we focus on a sample of 25 countries over the period 1970 to 1995. The out-of-sample performance of the "signals" approach will be assessed using data for the January 1996-June 1997 period.*

The countries in our list fall into four regional groupings, Africa, Asia, Europe and the Middle East, and Latin America and are those listed in Table 1.3. The basic premise of the signals approach is that the economy behaves differently on the eve of financial crises and that this aberrant behavior has a recurrent systematic pattern. This "anomalous" pattern, in turn, is manifested in the evolution of a broad array of economic and financial indicators. For instance, currency crises are often preceded by an "overvaluation" of the currency; banking crises tend to follow sharp declines in asset prices. The empirical evidence provides ample support for this premise.[1] However, in order to implement the signals approach, we need to clarify a minimum

[1] See Kaminsky, Lizondo and Reinhart (1998) for a survey of this literature.

number of concepts which will be used throughout the analysis.

## *Defining currency and banking crises*

***Currency Crises***: A currency crisis is defined as a situation in which an attack on the currency leads to substantial reserve losses and/or to a sharp depreciation of the currency--if the speculative attack is ultimately successful. This definition of currency crisis has the advantage that it is comprehensive enough to capture not only speculative attacks on fixed exchange rates, such as that of Thailand prior to July 2, 1997, but also attacks that force a large devaluation beyond the established rules of a crawling-peg regime or an exchange rate band, such as Indonesia's prior to its floatation of the rupiah on August 14, 1997. Since reserve losses also count, the index also captures unsuccessful speculative attacks, such as Argentina in the wake of the Mexican 1994 peso crisis.

For each country, balance of payments crises are identified by the behavior of an index of "exchange market pressure." This index is a weighted average of monthly percentage changes in the exchange rate and monthly percentage changes in gross international reserves in U.S. dollars (the latter with a negative weight).[2] Periods in which the index is above its mean by more than three standard deviations are defined as crises. As noted in earlier papers which use this approach, the dates of the crises map well onto the dates obtained if one were to exclusively rely on events, such the closing of the exchange markets or a change in the exchange rate regime.

[2] See Kaminsky and Reinhart (1996) for details on the construction of the index.

***Banking crises:*** The dating of banking crises stresses events.[3] Specifically, the beginning of a banking crisis is marked by either: (1) bank runs that lead to the closure, merging, or takeover by the public sector of one or more financial institutions or, (2) if there are no runs, the merging, closure, or large-scale government intervention or assistance of an important institution or group of institutions.

## *The Indicators*

Theory provides ample guidance on the choice of potential indicators. In addition to the 15 indicators originally considered in Kaminsky and Reinhart (1996), we evaluate the ability of nine additional indicators that figure prominently in both the theoretical literature on banking and currency crises and in the popular discussion of these events.[4] Four of these indicators are expressed as a share of GDP, these are: current account balance, short-term capital inflows, foreign direct investment, and the overall budget deficit. In addition, we look at the growth rates in general government consumption/GDP, central bank credit to the public sector/GDP, net credit to the public sector/GDP, and the current account balance as a share of investment. The

[3] Their paper discusses the relative merits of this definition.

[4] The indicators in that study were: (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); (6) the differential between 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; (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; (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). All the series are monthly. For greater detail, see the data appendix.

latter measure of the current account was motivated by the often-voiced view, particularly in the wake of the 1994-1995 Mexican peso crisis, that large current account deficits are more of a concern it they stem from low saving as opposed to high levels of investment. Recent events in Asia--a region noted for its exceptionally high levels of domestic saving and its even higher levels of investment--have lead to a reassessment of that view. As most of these indicators are not available at monthly or quarterly frequencies, annual data was used. In Chapter 4, we also examine the track record of sovereign credit ratings when it comes to "predicting" financial crises. Specifically, we examine the performance of the Institutional Investor and Moody's ratings.

For the monthly 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.[5] This filter has several attractive features: It reduces the noisiness of working with monthly data; it facilitates cross-country comparisons; and it ensures the variables are stationary with well-defined moments.

For the rating agencies, Institutional Investors constructs an index that is increasing in creditworthiness and ranges from zero to one hundred; this index is published twice a year and is released in March and September. Hence, we work with the 6-month percent change in this rating index. For Moody's, monthly changes are used; a downgrade takes on the value of minus

[5] Since there are two readings of this index per year, in a typical year (say 1995) we would have: the percent change in the rating from September 1994 to March 1995, that from March 1995 to September 1995, and the change from September 1995 to March 1996.

one, no change in the rating takes on a value of zero, and an upgrade takes on the value of one.[6]

[6] Since Moody's ratings take on values from 1 to 16, we also worked with changes in the ratings that took into account the magnitude of the change. This issue will be discussed in greater detail in Section IV.

Table 2.1 The Optimal Thresholds
(in percent)

| Indicator | Currency Crisis | Banking Crisis |
|---|---|---|
| Bank deposits | 15 | 20 |
| Central bank credit to the public sector | 90 | 90 |
| Credit rating (Institutional Investor) | 11 | 11 |
| Current account balance/GDP | 20 | 14 |
| Current account balance/investment | 15 | 10 |
| Domestic credit/GDP | 88 | 90 |
| Domestic-foreign interest rate differential | 89 | 81 |
| "Excess" M1 balances | 89 | 88 |
| Exports | 10 | 10 |
| Foreign direct investment/GDP | 16 | 12 |
| General government consumption | 90 | 88 |
| Imports | 90 | 80 |
| Lending/deposit interest rate ratio | 88 | 87 |
| M2 multiplier | 89 | 90 |
| M2/reserves | 90 | 90 |
| Net credit to the public sector/GDP | 88 | 80 |
| Output | 10 | 14 |
| Overall budget deficit/GDP | 10 | 14 |
| Real exchange rate[1] | 10 | 10 |
| Real interest rate | 88 | 80 |
| Reserves | 10 | 20 |
| Short-term capital flows/GDP | 85 | 89 |
| Stock prices | 15 | 10 |
| Terms-of-trade | 10 | 19 |

[1]An increase in the index denotes a real depreciation.

## *The Signaling window*

Let us call a signal (yet to be precisely defined) a departure from "normal" behavior in an indicator. For instance, an unusually large decline in exports or output may signal a future currency or banking crisis. Thus, if an indicator sends a signal that is followed by a crisis within a plausible time frame--this is labeled a good signal. If the signal is not followed by a crisis within that interval of time it is called a false signal, or noise. As in the earlier studies that have employed this approach the signaling window is set a priori at 24 months preceding the currency crisis. Hence, if that unusually large decline in exports alluded to earlier were to occur 28 months prior to the crisis, the signal would fall outside the signaling window and would be labeled a false alarm.

Hence, we have the following two by two matrix,

| | **Crisis occurs in the following 24 months** | **No crisis occurs in the following 24 months** |
|---|---|---|
| Signal | A | B |
| No signal | C | D |

A perfect indicator would only have entries in cells A and D. For banking crises we employ a different signaling window. Namely, any signal given in the 12 months preceding the beginning of the crisis or the 12 months following the beginning of the crisis is labeled a good signal. As discussed in Kaminsky and Reinhart (1996), the more protracted nature of the banking crises and the high incidence of denial that there are problems at the early stages of the crisis among both bankers and policymakers motivate the differentiated signaling window.

### *The threshold*

Suppose we wish to test the null or maintained hypothesis that the economy is in a "state of tranquility" versus the alternative hypothesis that a crisis will occur sometime in the next 24 months. Furthermore, suppose we wish to test this hypothesis on an indicator-by-indicator basis. As in any hypothesis test, this calls for selecting a threshold or critical value that divides the probability distribution of that indicator into a region that is considered normal or probable under the null hypothesis and a region that is considered aberrant or unlikely under the null hypothesis--the rejection region. Hence, if the observed outcome for a particular variable falls into the rejection region, that variable is said to be sending a signal.

Table 2.1 lists the thresholds for all the indicators for both currency and banking crises. For instance, the threshold for short-term capital flows as a percent of GDP listed in Table 2.1 is 85 percent. This conveys two bits of information. First, it indicates that 15 percent of all the observations in our sample (for this variable) are considered signals. Second, it highlights that the rejection region is located at the upper tail of the frequency distribution, meaning that a high ratio of short-term capital inflows to GDP will lead to a rejection of the null hypothesis of tranquility in favor of the alternative hypothesis that a crisis is brewing.

However, while the threshold or percentile that defines the size of the rejection region is uniform across countries for each indicator, the corresponding country-specific values are allowed to differ. Consider the following illustration. There are two countries, one which has received little or no short term capital inflows (as a percent of GDP) during the entire sample, while the second received substantially larger amounts (also as a share of GDP). The 85th

percentile of the frequency distribution for the low capital importer may be as small as ½ percent of GDP and any increase beyond that would be considered a signal. Meanwhile, the country where the norm was a higher volume of capital inflows is likely to have a higher critical value, hence, only values above, say, 3 percent of GDP would be considered signals. Table 2.2 illustrates this point by showing the country-specific critical values for export growth and annual stock returns for Malaysia, Mexico, and Sweden. A twenty five percent decline in stock prices would be considered a signal of a future currency crisis in Malaysia and Sweden but not in Mexico, with its far greater historical volatility. Indeed, as shown in Kaminsky and Reinhart (1998a), the volatility pattern for these three countries is representative of the broader historical regional pattern. Yet, the wild gyrations in financial markets in Asia in 1997-98 may be unraveling those historic patterns.

Table 2.2 Illustrative examples of country-specific thresholds: Currency crises

| **Country** | **Critical value for exports (12-month percent change)** | **Critical value for stock prices (12-month percent change)** |
|---|---|---|
| Malaysia | -9.05 | -15.20 |
| Mexico | -13.10 | -38.30 |
| Sweden | -11.25 | -20.78 |

Figure 2.1 provides an illustration over the emtire sample for our measure of the extent of overvaluation in the real exchange rate for Mexico. The horizontal line is the country-specific threshold and a reading below this line (recall a decline represents an appreciation), represents a signal. The shaded areas are the twenty four months prior to the crises, or the signaling window. Around 1982 the shaded area is wider due to the fact that there was a "double dip," as two crises were registered in 1982.

To select the optimal threshold for each indicator, we allowed the size of the rejection region to oscillate between 10 percent and 20 percent, for each choice the noise-to-signal ratio was tabulated and the "optimal" set of thresholds was defined as the one that minimized the noise-to-signal ratio; i.e., the ratio of false signals to good signals.[7]

In the next chapter, we describe the empirical results of applying the signals approach to the data.

[7]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.

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# APPENDIX A: DATA AND DEFINITIONS

**Crisis index:** The index is a weighted average of exchange rate 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 cataloged as crises. For countries in the sample that had hyperinflation, the construction of the index was modified. While a 100 percent devaluation may be traumatic for a country with low-to-moderate inflation, a devaluation of that magnitude is commonplace during hyperinflations. A single index for the countries that had hyperinflation episodes would miss sizable devaluations and reserve losses in the moderate inflation periods, since the historic mean is distorted by the high-inflation episode. To avoid this, we divided the sample according to whether inflation in the previous six months was higher than 150 percent and then constructed an index for each subsample. Our cataloging of crises for these countries coincides fairly tightly with our chronology of currency market disruptions. Eichengreen, Rose, and Wyplosz (1995) also include interest rates in this index, however, our data on market-determined interest rates for developing countries does not span the entire sample.

**The indicators:**

Sources: International Financial Statistics (IFS), International Monetary Fund; Emerging Market Indicators, International Finance Corporation (IFC); World Development Indicators, the World Bank, when data was missing from these sources, central bank bulletins and other country-specific sources were used as supplements. Unless otherwise noted, we used **12-month percent changes**.

**1. M2 multiplier:** The ratio of M2 to base money, (IFS lines 34 plus 35) divided by IFS line 14.

**2. Domestic credit/nominal GDP**: IFS line 52 divided by IFS line 99b (interpolated). Monthly nominal GDP was interpolated from annual or quarterly data.

**3. Real interest rates on deposits**: IFS line 60l, monthly rates, deflated using consumer prices (IFS line 64) expressed in percentage points.

**4. The ratio of lending rates to deposit rates**: IFS line 60p divided by IFS line60l; was used in lieu of differentials to ameliorate the distortions caused by the large percentage point spreads observed during high inflation. In levels.

**5. "Excess" real balances:** M1 (IFS line34) 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 line99b), 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 (which can enter log-linearly, linearly, or exponentially) is motivated by its role as a proxy for financial innovation and/or currency substitution. Excess money supply (demand) during pre-crisis periods (mc) is reported as a percent relative to excess supply (demand) during tranquil times (mt)--that is, 100 x (mc-mt)/mt.

**6. M2 (in US dollars)/reserves (in US dollars):** IFS lines 34 plus 35 converted into dollars (using IFS line ae) divided by IFS line 1L.d.

**7. Bank deposits:** IFS line 24 plus 25.

**8. Exports (in US dollars)**: IFS line 70.

**9. Imports (in US dollars):** IFS line 71.

**10. The 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.

**11. The real exchange rate:** This measure used is based on consumer price indexes (IFS lines 64) and is defined as the relative price of foreign goods (in domestic currency) to the price of domestic goods. If the central bank of the home country pegs the currency to the dollar (Deutsche mark), the relevant foreign price index is that of the United States (Germany). Hence, for all the European countries the foreign price index is that of Germany while for all the other countries, consumer prices in the United States were used. The trend was specified as, alternatively, log-linear, linear, and exponential; the best fit among these was selected on a country-by-country basis. Deviations from trend during crisis periods (dc) were compared to the deviations during tranquil times (dt) and are shown in Figures 2 and 3 as a percent of the deviations in tranquil times (i.e.,100 x (dc-dt)/dt).

**12. Reserves:** IFS line 1L.d**.**

**13. Domestic-foreign interest rate differential on deposits:** Monthly rates in percentage points. IFS lines 60l. Interest rates in the home country are compared with interest rates in the United States (Germany) if the domestic central bank pegs the currency to the dollar (Deutsche mark). The real interest rate is given by $100 \times [((1+ i_t)p_t / p_{t+1-1}]$.

**14. 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).

**15: Stock returns (in dollars):** IFC global indices are used for all emerging markets; for industrial countries the quotes from the main bourses are used.

**16. Overall budget balance/GDP:** Consolidated public sector balance as share of nominal GD