

LEADING INDICATORS OF CURRENCY AND BANKING CRISES: CROATIA AND THE WORLD*

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1 INTRODUCTION

The balance of payments crises that have shaken the world in the last two decades have awakened interest in academic and political circles in creating systems for discovering the causes of the disturbances that end in currency crisis. If disturbances on foreign exchange markets could be identified early enough, there might be enough time for policymakers to take measures to avoid or at least diminish the severity of such crises. With this in mind, the present work attempts to develop such a system of early warning for currency crises in Croatia.

However, the number of theoretical and empirical works on the potential links between banking and balance-of-payments crises is growing continuously. Research on these problems in a large number of countries has shown that banking problems help in the prediction of balance-of-payments crises. Many of the countries that have faced currency crisis have to a greater or lesser extent also faced banking crisis (recent examples include Finland, Mexico, Norway and Sweden). The International Monetary Fund estimates that banking crisis are more "expensive" than currency crisis, pointing out that the typical currency crisis

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induces a fall in domestic output of 4 percent to 7 percent, while twin (banking and currency) crises induce falls of up to 15 percent (IMF, 1998). The macroeconomic situation in Croatia in 1998 and in early 1999 provides sample room to test this argument.

A thorough examination of the literature on twin crises would be an extremely demanding theoretical and empirical task. Therefore, I will limit myself to see which of the signaling indicators for twin crises suggested in the literature would have the most value in Croatian conditions. However, the "signals" approach can only be developed if the economy has experienced either currency or banking crisis in the past that can be used to make an ex-post analysis of the behavior of key variables.

I begin this article with a short overview of theoretical and empirical analyses of currency and banking crisis. I will only mention works that dealt with individual crises, and place greater emphasis on more recent cross-country studies that examine the connection between banking and currency crisis in an attempt to find common causes. The macroeconomic consequences of these crises are my main concern, as well as the possibility that earlier deterioration in key economic conditions provides a signal of upcoming crisis. After that, I will examine the Kaminsky-Lizondo-Reinhart methodology of the "signals" approach more closely, as well as the results of the analysis of twin crises in various countries. Special attention will be paid to the attempt to apply this method to a sample of transition countries. All of this will provide an introduction to the final section, which examines the feasibility of using the "signals" approach in the case of Croatia.

2 LINKS BETWEEN CURRENCY AND BANKING CRISIS-THEORY AND PRACTICE

The theoretical examination of balance-of-payments crisis or currency crisis began with Paul Krugman's (1979) article. However, the literature only really began to blossom in the middle of the 1980's. In previous studies based on the traditional approach, the cause of currency crises was considered to be weak fundamentals. These weaknesses, further aggravated by expansive fiscal and monetary policies, resulted in continuous declines in international reserves and the collapse of the exchange rate regime.¹ Although the *Krugman model* has

¹ Thus the well-known Krugman model (1979) suggests that, under a fixed exchange

been amended and reformulated repeatedly over time, models using this approach usually emphasize the following potential indicators of currency crisis: movements in the real exchange rate, merchandise trade balance or current account, real wages and interest rates.

Recent models abandon explanations that give international reserves the key role in undermining fixed exchange rates systems. Instead, they suggest that exchange rate fluctuations are the result of economic authorities' concerns over the behavior of other key economic variables.² The latest models extend the group of indicators of currency crisis to variables that can undermine the objective function of the economic authorities. Most often these variables are domestic and foreign interest rates, the level of public debt, government bond prices along with those of other debt securities held by the banking system, central bank lending to commercial banks, deposits, various political variables and "contagion" effects.

The best known of the newer models is the "self-fulfilling" model of currency crisis. This model shifts the emphasis from economic fundamentals to the expectations held by economic agents (Obstfeld, 1986). The self-fulfilling model suggests that speculative attacks on the currency and changes in equilibrium occur because of changes in actors' expectations, even when fundamental macroeconomic variables are not perturbed.

The literature on currency and banking crisis consists mainly of three groups of studies. One group consists of studies that seek the causes of banking panics and the causes of banking crises.³ A second group consists of studies that explain the causes of currency crises. Although this group of studies has a richer theoretical basis to draw on than the first, the same cannot be said for their empirical content.⁴ The third group of studies examines possible links between banking and currency crises, calling these "twin" crises. Although at times

rate, currency crises are preceded by periods of gradual but prolonged decreases in international reserves and credit expansion that exceeds the demand for money or fiscal imbalances along with increases lending to the public sector. In these conditions, continuous decreases in foreign exchange reserves stimulate speculative attacks on the domestic currency, which further exhausts reserves and forces the economic authorities to devalue.

² See Ozkan and Sutherland (1995); Velasco (1987); Obstfeld (1986, 1994, 1996) and Gerlach and Smets (1994).

³ An overview of this literature is found in Clamorous and Gorton (1991), Kaminsky and Reinhart (1996) and Fred (1999).

⁴ See: Agent, Bandar and Flood (1992) who research traditional models; Obstfeld (1994, 1996) which gives a literature survey on self-fulfilling currency crises; Calve (1995) which discusses various models of balance-of-payments crisis; and Eichengreen, Rose and Wyplosz (1995) which studies successful and unsuccessful speculative attacks on the currencies of developed industrialized countries.

it is difficult to make a sharp distinction between these groups of studies,⁵ without a doubt only in recent times have serious efforts been made to examine the connections between currency and banking crises. These efforts have been sharply intensified since the Asian crisis.

2.1 "Twin" crises: basic concepts and macroeconomic effects

As has already been mentioned, studies examining both types of crisis and their possible connections are still very rare, although greater interest has been shown in making them the subject of all-sided inquiry.⁶ The understanding that financial liberalization precedes many banking crises has been spreading, as has the understanding that banking crises often precede balance-of-payments problems and help in forecasting currency crisis. At the same time, there is inadequate evidence of the opposite link, from currency crises to banking crises. The pioneering work that brought the concept of twin crisis into the literature was that of Kaminsky and Reinhart (1996). Examining countries that experienced currency and banking crises in the years 1970-1995, Kaminsky and Reinhart construct an index of banking and balance-of-payments crises based on an analysis of movements in exchange rates and international reserves, as well as a chronological account of events. The authors believe that this "classification" of crises allows us to draw conclusions about possible causal relations between currency and banking crises. They are most interested in the behavior of various domestic and international macroeconomic variables in the periods before and after crises, and in whether it is possible to find common macroeconomic causes for these crises. Their main conclusions can be summarized as follows:

- (1) There is no evidence of strong connections between currency and banking crises in the 1970's, when financial markets were highly regulated. The weakening of capital regulations in the early 1980's strengthened this connection, however. The majority of banking crises occurs in the 1980's and 1990's, after financial liberalization, in developing countries, but also in developed countries.

⁵ For example, Krugman (1979) quite clearly takes both types of crisis into account, although he does not look for common causes nor for the direction of causality.

⁶ Theoretical studies of the connection between banking and currency crises can be found in: Diaz-Alejandro (1985), Velasco (1987), Calvo (1995), Goldfajn and Valdes (1995), Kaminsky and Reinhart (1996) and Chang and Velasco (1998).

- (2) Most often banking crises precede currency crises, and reach their peak during the currency crisis (if it occurs at all).⁷
- (3) The roots of the crises are various domestic and foreign shocks. Very often recessions precede banking and currency crisis, manifesting themselves in general economic weakness, decreases in economic activity and exports, worsened terms of trade, growing real interest rates and contracting securities markets. Balance-of-payments crises are preceded by decreases in foreign exchange reserves, rapid monetary growth, and growth in banking assets uncovered by increased foreign exchange reserves. Rapid credit expansion and growth in the money multiplier precede banking crises.

Studies attempting to find leading indicators of twin crisis vary in coverage. Often they differ in the time period considered; some of them include as much as the last thirty years, while other only look at events in a single year. Some studies consider large samples including many countries, while some concentrate on only one country. More papers examine developing countries than developed countries. However, all studies have to face the difficult problem of defining a crisis. Crises may include certain events, for example, devaluation, but there are cases where such events are not required for a crisis.

Defining currency crises

Balance of payments crises most frequently are linked to devaluation or changes in the exchange rate regime, although up to now, no measure has been created to measure the size of the devaluation that is so crucial to defining crises. More recently, a more acceptable solution has been found in defining currency crises through monitoring the movements of exchange rates and international reserves (Eichengreen, Rose and Wyplosz, 1995). In this view, not every attack on the domestic currency results in changes in the exchange rate regime. If a speculative attack succeeds, the currency will indeed devalue. However, when the attack is less successful, the central bank will have room to intervene on the foreign exchange market. This, along with restrictive monetary policy will result in gradual increases in real interest rates or, perhaps, greater decreases in international reserves.

⁷ *The authors show that in the case of twin crises, most frequently banking crises occur first, followed by balance-of-payments problems. This becomes obvious in the end of the 1980's and during the 1990's.*

Because of this, the construction of an *index*⁸ of currency crises that can "catch" all the manifestations of an attack on the currency is proposed. Such an index is a weighted average of the monthly growth rates of the exchange rate and international reserves. The index is usually interpreted in a straightforward manner: a crisis period is a period in which the value of the crisis index is two (or three) standard deviations above or below its mean value. Otherwise, the period is considered normal. This measure expresses at the same time the degree of loss of reserves and the degree of volatility of the exchange rate, and thus allows crises to be ranked by degree.

Defining banking crises

Although changes in banking deposits can be used as a sign of banking crisis, the fact is that problems are more frequently on the asset side of banks' balance sheets (Kaminsky and Reinhart, 1996). The beginning of a banking crisis most frequently is denoted by a *specific event* such as a run of depositors, the failure and closure of a particular bank, or growth in banks' past due claims. An important characteristic of banking crises is that they usually last longer than currency crises. The peak of a banking crisis is the moment at which a significant number of banks, with a substantial share in the total assets of the banking system as a whole are closed, or when economic authorities began a program of clean-up or rehabilitation.

Macroeconomic background of currency and banking crises

Kaminsky and Reinhart (1996) undertook an extensive empirical analysis of the links between currency and banking crises based on a sample of twenty countries.⁹ The sample includes 25 banking and 71 currency crises. The authors' analysis of the chronology of events allowed them to make the following observations about the macroeconomic background and effects of crisis:

⁸ See Eichengreen, Rose and Wyplosz (1995) and Kaminsky and Reinhart (1996).

⁹ The sample included Denmark, Finland, Norway, Spain, Sweden, Argentina, Bolivia, Brazil, Chile, Columbia, Indonesia, Israel, Malaysia, Mexico, Peru, the Philippines, Thailand, Turkey, Uruguay, Venezuela (Kaminsky and Reinhart 1996).

- (1) The types of crises vary in different subperiods: during the seventies, twenty currency crises but only three banking crises occurred, mostly due to the high degree of financial regulation at the time. In the eighties and nineties, the number of balance-of-payments crises did not change substantially, but the number of banking crises rose substantially. The authors connect the increased number of banking crises with the financial liberalization.
- (2) Using a probit model, the authors evaluated the links between the index of currency crisis and the index of banking crisis. Lags of 12 to 36 months were used, including a dummy variable for financial liberalization. The results of the test show that banking crises significantly aid in the prediction of balance-of-payments crisis, but not vice versa.
- (3) Twin crises have common roots in the deregulation of the financial system,¹⁰ in credit expansion and deterioration of the balance-of-payments.
- (4) The external manifestations of crises and the constructed indices of crises usually coincide.
- (5) Currency crises are much sharper and more dangerous in emerging market economies than in developed economies.
- (6) External factors (foreign interest rates) have a significant role in forecasting currency crisis. In this respect, the authors' views converge with some previous studies (for example Frankel and Rose, 1996; Eichengreen, Rose and Wyplosz, 1995).

In order to analyze the *macroeconomic background of currency crises*, Kaminsky and Reinhart (1996) examine the behavior of groups of macroeconomic and financial variables one and a half years before the crises, and after the crises. The variables used are: real exchange rate, value of exports and imports, terms of trade, index of production, M1, international reserves, M2/international reserves and the difference between domestic and foreign interest rates.

The authors argue that declines in economic activity or recessions usually precede currency crises. In this, they do not diverge from

¹⁰ The authors find that financial liberalization had occurred in the 5 years preceding 70 percent of the banking crises. Also, the financial liberalization dummy was significant in all the specifications used for predicting banking crises, but not in the specifications used for predicting currency crises.

previous studies that show that the rate of unemployment is high during the period preceding currency crises.¹¹ Which unusual changes one can find in the behavior of individual variables in the immediate pre-crisis period and immediately after the start of the crisis?

A strong appreciation of the currency before the start of the crisis negatively affects exports, which are on average 20 percent lower at the onset of crises than in normal periods. Because of decreases in overall economic activity in the pre-crisis period imports may reach their lowest rate of growth (or even fall) as early as a year before the crisis. After the crisis, imports tend to recover slowly. Deterioration in the terms of trade leads currency crisis by about twelve months, and of course can lead to decreases in output. If the economic authorities devalue in order to overcome negative trends in exports and output, a "bad" equilibrium is possible in which expectations about the growth of nominal wages further harms competitiveness and creates pressure for further devaluation. Analysis of particular cases shows that recovery is a very slow process that may last as long as one and a half years from the start of the crisis, despite measures to improve the terms of trade.

Monetary policy usually becomes expansive about six months before the start of currency crises. In the pre-crisis period, almost all monetary aggregates usually grow. The danger of a gradual and permanent loss of foreign exchange reserves grows, and high interest rate differentials¹² immediately before the crisis may be a sign of increased risk premia or monetary policy tightening to preserve international reserves.

In the analysis of the *macroeconomic environment in which banking crises occur*, the authors add a number of financial and monetary variables to the indicators of currency crisis.¹³ These variables provide a more detailed picture of the pre and post-crisis behavior: index of securities prices, bank lending to the private sector, money multipliers ($M1/M0$, $M2/M0$), real deposit interest rates and commercial bank deposits.

At cyclical peaks, bank leverage is at its highest. Optimistic expectations lead to increased credit activity by the banking sector. Such increased lending can begin as much as 18 months prior to the start of the banking crisis, and may be stimulated by capital inflows and financial liberalization. However, economic reversal along with worsened terms of trade and weakening on securities

¹¹ For example Eichengreen, Rose and Wyplosz (1995).

¹² Calvo (1995) and Obstfeld (1994, 1996) see the interest rate differential as one of the key variables that makes a crisis self-fulfilling.

¹³ Terms of trade, index of production, real exchange rate and international reserves.

markets and real estate markets, decreases the profitability of banks' clients. Many firms become unable to service their obligations in a timely manner. The riskiness of a large portion of banks' portfolios increases, imperiling the health of the whole banking system. A recession usually begins about twelve months before serious banking sector problems emerge, and the fall in economic activity is reflected almost immediately in the securities and real estate markets. With the recession, depositors' fears about the stability of particular financial institutions and the banking system as a whole increase. Depositors' behavior, in turn, may further weaken the financial system of the country.

In the majority of the countries studied, the authors note strong effects of the money multiplier in the pre-crisis period. They see this as a result of decreases in reserve requirements, which are certainly the result of the financial deregulation process in late seventies and early eighties. Financial reforms were one cause of the growth in real interest rates, which in pre-crisis periods exceed normal rates by at least 1 percent. High real interest rates are in part an expression of the measures taken by the central bank to control the liquidity of the banking system to defend the value of the currency. However, such steps may push a fragile banking system step by step into crisis.

2.2 The traditional approach to analyzing the cause of crises

When examining the methodological attempts to find economic variables that provide early warning of currency or banking crises, we can separate two key approaches: *the traditional approach and the most recent "signals" (nonparametric) approach*. The first approach generally tries to use econometric tests to find the causes of balance-of-payments crises. Those studies that provide qualitative description of pre-crisis events¹⁴ can also be considered traditional. The same is the case with various parametric and nonparametric tests of the influence of particular variables on exchange rate stability¹⁵ and various estimates of the probability of currency crisis based on explicit theoretical models. This last method has developed under the methodological influence of Blanco and Garber (1986),

¹⁴ See Dornbusch, Goldfajn and Valdes (1995).

¹⁵ Some studies compare the behavior of variables in pre-crisis periods with their behavior in "normal" period in countries in the same group (Eichengreen, Rose and Wyplosz, 1995; Frankel and Rose, 1996). Others compare the behavior of variables in countries with currency crisis with the behavior of the same variables that did not suffer currency crises (Edward, 1989; Kamin, 1988).

who are pioneers in estimating the probability of currency crisis.¹⁶ Although the majority of works are focused on the causes of currency crisis, more recent works include studies of early warning indicators of banking crises.¹⁷

Despite various attempts to differentiate approaches, the traditional methodology for estimating the probability of crisis is quite uniform.¹⁸ That is, studies using this methodology most often define crises via an index of pressure on the foreign exchange market.¹⁹ This index is influenced by changes in international reserves, exchange rate and interest rate. The probability of crisis is estimated via probit or logit models with maximum likelihood estimation. Most often, the models test whether spillover effects played a significant role in currency crises. Because of the assumption that worsening economic conditions gradually culminate in a crisis, the models use lagged variables.

The advantage of the traditional method (estimation of the probability of crisis) is its simple interpretation. All information about a future crisis is contained in a single number. However, it seems that this advantage is also a disadvantage of the method. This approach does not allow the researcher to rate indicators according to their relative predictive power. Either variables are significant or they are not, and if they occasionally send incorrect signals, the methodology cannot detect this. This methodology hardly could tell us what "went wrong" in global economic activity as well as how to reformulate economic policy to avoid a crisis.

¹⁶ Authors used these methods in analyzing the Mexican crisis of the early eighties. Frankel and Rose (1996) continue this tradition (sample of 105 developing countries), Eichengreen, Rose and Wyplosz (1996) analyze the spill-over effects between twenty developed countries, and Sachs, Tornell and Velasco (1996) analyze the Tequila effects. Some studies used these methods to analyze particular cases of devaluation (Cumby and Wijnbergen 1989; Ötoker and Pazarbasioglu, 1994, 1995); some compare differences in the degree of exchange rate disturbance between countries (Edin and Vredin, 1993; Edwards, 1989; Klein and Marion, 1994). Recent works, that of Kruger, Osakwe and Page (1998) uses a sample of 19 developing countries to study whether currency crises are results of deterioration in economic conditions or spill-over effects.

¹⁷ For example Hardy and Pazabasioglu (1998), Demirguc-Kunt and Detragiache (1998).

¹⁸ The studies which confirm this uniformity of approach are: Eichengreen, Rose and Wyplosz (1995, 1996) and Kruger, Osakwe and Page (1998).

¹⁹ Using this method, Eichengreen, Rose and Wyplosz (1995, 1996) identify 77 currency crises in the years 1959 to 1973.

2.3 The "signals" approach -an overview of the method

The "signals" approach attempts to overcome the difficulties and limitations faced by the traditional method in building a specific early warning system for currency and banking crises. The starting point is that disturbances that may lead to crisis do not happen accidentally, but are the result of gradual deterioration in economic conditions. *This approach begins with a detailed analysis of the behavior of variables whose movements in the pre-crisis period differ substantially from their usual behavior in normal economic conditions.* A substantial deviation of a variable (either below or above the trend) is seen as a warning signal of possible currency or banking crisis. The "signals" approach was founded by Kaminsky and Reinhart (1996) as an alternative method which facilitates deeper understanding of the behavior of the macroeconomic forces that pushed the country into crisis. The idea of developing a system of economic indicators that can anticipate crises derives from the literature on business cycles and the methods used to forecast business cycle turning points.²⁰ The "signals" approach is a very young one. In the future, one can expect a more detailed empirical testing of the usefulness of the method for analytical and forecasting purposes.²¹

The difficulties in creating such an early warning system for Croatia include the short time horizon for analysis and the fact that experience in using such models is inadequate. Although the economists engaged in this field generally agree on key methodological steps, the method itself allows some analytical flexibility to take into account variations in the economic situations in particular countries. Therefore, in this section we will first examine the method itself, including its key definitions and analytic criteria. After this, we will provide a short overview of the most important empirical results from tests of the method in the analysis of currency and banking crises in various countries, with special attention to transition countries.

²⁰ *This refers to the well-known barometric method that is used to monitor and forecast economic activity. In Croatia, the so-called CROLEI (CROatian Leading Economic Indicators) system has been developing for almost six years to monitor and forecast overall economic activity.*

²¹ *Thus, it is not strange that several studies have already appeared examining the possibilities of using this method to analyze banking and currency crises. See Kaminsky, Lizondo and Reinhart (1997), Kaminsky (1998), Berg and Pattillo (1998), Bruggemann and Linne (1999).*

Defining crises and choices of potential indicators

Banking crisis are most often defined by a particular event: a bank run, the closure of a bank, the take over or merger of a bank, or the beginning of a rehabilitation program for an "unhealthy" bank. Currency crises are defined as situations in which speculative attacks on the currency lead to a substantial depreciation, a substantial decrease in international reserves or a combination of one and the other. This approach rests on a broad definition that includes both successful and unsuccessful attacks on various exchange rate regimes.

As in the original leading indicator's approach, the key step in the analysis is the definition of the reference series whose behavior is analyzed and predicted by the system of warning indicators.²² Kaminsky and Reinhart (1996) suggest that currency crises should be identified by the behavior of an "*index of foreign exchange market pressure*". This index is a weighted average of monthly percentage changes in the exchange rate (defined as units of domestic currency per \$US or per German mark) and the monthly percentage changes in total international reserves (with a negative sign). Because of the depreciation of the currency and because of the decreased international reserve the exchange market pressure index grows, expressing strong pressure on domestic currency. A period in which the index is more than three standard deviations above its average value is defined as a crisis period. However, this condition should be modified in countries experiencing high inflation: periods must be divided into periods of lower and higher inflation, with separate calculation of the index for each sub-period.

The choice of potential signaling indicators whose behavior in the pre-crisis period is to be tested is based on theory and on the availability of monthly data. In the analyses of currency crises undertaken so far (Kaminsky and Reinhart, 1996; Kaminsky, Lizondo and Reinhart, 1997) the following variables have been found to provide signals about upcoming currency crises: international reserves, imports and exports, terms of trade, real exchange rate and its deviation from trend, the differential between domestic and foreign real interest rates on deposits, the difference between real M1 and an estimated demand for money), money multiplier (M2), domestic credit/GDP, real deposit interest rates, the ratio of nominal lending to deposit interest rates, the stock of deposits at commercial banks, M4/international reserves, the index of output and the index of equity prices. Other than the real exchange rate and interest rates, all these variables are expressed as annual growth rates.

²² For example, the key reference series in the Croatian CROLEI system of indicators is the index of industrial production.

The signal horizon

The signal horizon is the period before the crisis during which the behavior of the indicators signals the upcoming crisis. The time horizon can vary from one to two years, so the majority of authors chose a period of 18 months before the start of the crisis. For banking crisis, the analysis often continues in the post-crisis period, to follow the development of the macroeconomic situation in general and the recovery of the banking system.

Signals and critical values (thresholds)

The indicators provide signals when they substantially differ from their trend. That is, when the deviation exceeds certain critical values, a signal is sent. The critical values are set to achieve a certain balance between the risk of sending *false signals (noise)* and the risk of ignoring *good signals* of a crisis that is in fact impending. The optimal critical values are defined as those that minimize the noise-to-signal ratio (the ratio of false to good signals).

The usefulness of indicators for predictive purposes can be examined through a "scoring system" of potential indicators. The scoring system is based on:

- (1) estimates of the forecasting ability of each potential indicator,
- (2) estimates of the "lead-time" of indicators,
- (3) estimates of the persistence of their signals.

The most important criterion for assessing the effectiveness of indicators is the confirmation of their reliability in signaling future crisis. The performance of each indicator can be estimated in terms of following matrix (Table 1):

Table 1

MATRIX OF ESTIMATION OF POTENTIAL INDICATORS (within 2 years)

	crisis	no crisis
signal exist	A	B
signal does not exist	C	D

Source: Kaminsky, Lizondo and Reinhart (1997).

In above matrix, *A* is the number of months in which the indicator issued good signs for upcoming crisis, *B* is the number of months with bad signal (noise), *C* is the number of months without a signal but a crisis follows, and *D* is the number of months without a signal and no crisis follows.

This matrix shows four "ideal" cases, since in reality no indicator will really satisfy the criteria of the matrix. However, the matrix is useful in establishing which indicators are closer and which are farther from the ideal characteristics. An ideal indicator is one that produces a signal in every month within the signal horizon (1 to 2 years) before a crisis, so that $A > 0$ and $C = 0$, or one which does not produce any signals in time horizon that is not to be followed by a crisis, so that $D < 0$ and $B = 0$.

Based on this matrix, it is possible to calculate measures that serve to help in ranking indicators according to their predictive power. Kaminsky, Lizondo and Reinhart (1997) propose calculating the percentage of crises correctly predicted as the percentage of total crises for which the indicator provides at least one signal during the signaling horizon (1 or 2 years).²³

The next measure derived from the matrix is the share of good signals in total signals, expressed as $A/(A+C)$. In this case, the maximum score (100 percent) would belong to an indicator that sent signals in every month within the signaling horizon before every observed crisis. It is also possible to calculate the number of bad signals (noise) sent by an indicator, as well as the share of bad signals in the number of months in which false signals could have been sent ($B/(B+D)$).

The key measure calculated on the basis of the matrix is the *adjusted noise-to-signal ratio*. The noise-to-signal ratio provides information about the success of the indicator in producing good signals and avoiding false signals.

²³ Thus, for example a score of 100 percent would mean that the indicator produces at least one good signal within the signaling horizon before each crisis. Kaminsky, Lizondo and Reinhart (1997) calculated that the indicators chosen for their sample of countries succeeded in signaling about 70 percent of the total number of currency crises observed.

This ratio is calculated as the simple ratio between the above two measures ($B/(B+D)/A/(A+C)$). The lower this ratio is for a particular indicator, the more successful is the indicator in predicting future currency or banking crises. The adjusted noise-to-signal ratio is considered the key measure in the choice of a short list of the best leading indicators of crisis. Therefore, all those variables whose noise-to-signal ratio is equal to or greater than one are removed from the analysis. The last measure for estimating the quality of the signal is the comparison of the probability of crisis conditional on a signal from the indicator ($A/(A+B)$) with the unconditional probability of a crisis ($(A+C)/(A+B+C+D)$). The conditional probability is greater than the unconditional one only for those indicators that have predictive power.

The choice of the most successful indicators depends on *the lead-time of the indicator*. It is not a matter of indifference if the indicator sends a signal of a crisis in twelve months time or in one month's time. Because of this, it is necessary to establish the signal horizon of each individual indicator; i.e. how many months before the crisis the indicator produces first warning signal.

The last criterion for assessing an indicator is the confirmation of the persistence of the signals during the signal horizon, defined as the average number of signals per period. The measure of persistence of the signal is simply the inverse of the adjusted noise-to-signal ratio, and expresses the persistence of the signal in the pre-crisis period as opposed to the "normal" period.

The main advantages of the "signals" approach are its methodological clarity and simplicity. Today, this is not subject to debate among economists. What is subject to debate and open questions is the possibility of using this approach in various empirical analysis that examine various samples of countries, as well as the quality of the information that the signal approach provides to analysts and policymakers. The creators of this approach believe that it can be very effective and useful as the basis of the construction of an early warning system for currency and banking crises. Furthermore, the results of their analysis confirm an existence of a large number of indicators that anticipate and signal future crises during the pre-crisis period. The authors of the "signals" approach also consider it positive that their approach does not substantially differ from other empirical studies based on traditional analytical methods.²⁴ The Kaminsky-Lizondo-Reinhart (KLR, as it is often called in the literature) approach has shown the predictive power of a majority of the indicators of crisis developed with the traditional techniques in the various studies undertaken to date.

²⁴ Berg and Pattillo (1998), who test three models for predicting currency crises, come to this conclusion. Those three models are: the "signals" (Kaminsky-Lizondo-Reinhart) approach, the probit model for a large sample of countries proposed by Frankel and Rose (1996) and the regression analysis based on time series from a large sample of countries done by Sachs, Tornell and Velasco (1996).

3

EMPIRICAL TESTS OF THE "SIGNALS" APPROACH

In this chapter, I take a more detailed look at the two most important empirical tests of the signal method undertaken to date. The first complex empirical test was made by Kaminsky-Lizondo-Reinhart, and is based on research on currency crises in a sample of various countries. The second is a newer study that represents an interesting attempt to apply the signal approach to a smaller sample of transition countries. For our research, this study is especially important because its analysis includes twin crises, and because the countries studied have passed through the transition process and continue to face similar problems and challenges to those Croatia faces.

3.1 Testing the system of "early warning" for currency crises

Before beginning to test the "signals" approach on a large sample of countries, Kaminsky, Lizondo and Reinhart (1997) carefully examined empirical results from 25 research studies.²⁵ These studies mainly used the traditional approach for examining possible indicators of currency crisis. Summarizing the results of these studies, the authors put together a broad list of all the known potential indicators of currency crisis. The list includes 103 variables divided into several key categories (see Appendix 1).

Based on this list, the authors attempted to identify indicators with predictive power and statistically significant contributions to the analysis of currency crises. They were aware that the majority of studies used traditional methods (mainly econometric tests and estimates of the probability of crisis) and that the predictive power of each indicator was expressed quantitatively. Although there is no simple answer to the question which indicators are the best indicators of crisis, most studies pointed to the following variables as the most reliable: *international reserves, real exchange rate, credit expansion, credit to the public sector and the rate of inflation*. To obtain a predictive system, it was necessary to

²⁵ Some of them are: Bilson (1979), Blanco and Garber (1986), Cumby and Van Wijnbergen (1989), Dornbusch, Goldfajn and Valdes (1995), Edin and Vredin (1993), Edwards (1989), Edwards and Montiel (1989), Eichengreen, Rose and Wyplosz (1995), Frankel and Rose (1996), Kamin (1988), Kaminsky and Leiderman (1996), Kaminsky and Reinhart (1996), Klein and Marion (1994), Krugman (1979), Moreno (1995), Otker and Pazarbasoglu (1994, 1995) and Sachs, Tornell and Velasco (1995).

test other variables as well and to take into account the specificity of each national economy.

In order to examine the effectiveness of the "signals" method, the authors extended their previous research (Kaminsky and Reinhart, 1996) and analyzed a total of 76 currency crises in the period 1970-1995 in a sample of 15 developing countries and 5 developed countries. I will not burden the present discussion with a repetition of the original methodological steps taken by the signaling approach, but instead will provide a short overview of the main results of the paper.

The authors selected indicators and created a shorter list of 15 reliable economic indicators (Table 2). These indicators proved reliable in the majority of previous empirical studies of currency crises. All the variables except the real exchange rate and interest rates are expressed as annual growth rates.

Table 2

POTENTIAL LEADING INDICATORS OF CURRENCY CRISIS

1. International reserves	8. Money multiplier (M2/M0)
2. Imports	9. Credit/GDP
3. Exports	10. Real deposit interest rates
4. Terms of trade (ratio of import to export unit value)	11. Relation between domestic nominal lending and deposit interest rates
5. Deviation of real exchange rate index from trend	12. Deposits in commercial banks (nominal)
6. Difference between domestic and foreign real deposit interest rates	13. M4/International reserves
7. Monetary equilibrium (difference between M1 and estimated demand for money)	14. GDP index
	15. Index of share prices

Source: Kaminsky-Lizondo-Reinhart (1997).

As we mentioned earlier, the authors define currency crises using the index of foreign exchange market pressure. The index is a weighted average of the monthly percentage change in the exchange rate and in total international reserves (inverted series). The weights are chosen so that each component has an equal conditional variance. The index rises due to depreciation and decreased international reserves, expressing the increased pressure on the currency. This definition of crisis is wide enough to cover not only speculative attacks on fixed exchange rate regimes, but also attacks on other exchange rate systems. The authors choose a signal horizon of 24 months before the start of the crisis. All signals sent in that period are considered reliable. The indicator gives a

signal whenever it substantially deviates from its trend beyond a given critical value. For each individual indicator and for each country in the sample, the optimal level of deviation²⁶ from the mean value is determined. The critical value is determined to achieve a balance between the risk of receiving many false signals and the risk of missing good signals when a crisis is impending.

Using the matrix, the authors estimate the usefulness of each individual indicator. The results of the study are shown in Appendix 2. In the period studied, various indicators succeeded in "predicting" almost 70 percent of the total of crises. This means that the indicators produced at least one good signal in the 24 months before about 70 percent of the crises. However, the number of the months in which good signals could have been issued ($A/(A+C)$) introduces considerable strictness in the analysis²⁷. The authors conclude that the real exchange rate is the one that issued the highest percentage of possible good signs (25 percent), followed by international reserves (22 percent), M2/international reserves (21 percent), the M2 multiplier (20 percent), exports and the price of securities (17 percent), and imports (the lowest rate 9 percent).

The percentage of months in which false signals were possible ($B/(B+D)$) showed that the real exchange rate produced the smallest percentage of bad signals (only 5 percent), followed by exports (7 percent), the price of securities and output (8 percent), the share of credit in GDP (9 percent). The worst indicator was the relationship between lending and deposit interest rates (22 percent false signals).

The adjusted noise-to-signal ratio which is the ratio of the two measures above was again best (lowest) for the real exchange rate (0.19), followed by exports (0.42), price of securities (0.47), M2/international reserves (0.48), international reserves (0.55). The poorer performers included imports (1.16), deposits (1.2) and the relation between lending and deposit interest rates (1.69). This measure is crucial in the choosing the final list of leading indicators of currency crisis. Variables with scores above one were removed from the list. The

²⁶ For example, possible limits for the import variable include growth rates (for each country) for which 10 percent of the observations remain above the limit for each country. This percentage is taken as a unified criterion for all countries, but within each country this limit can vary. Using a network of reference percentage deviations (from 10 to 20 percent), the authors arrive at an optimal set of limits that minimizes signal errors (that is, the relation between incorrect and correct signals). Among the variables whose decrease signals crisis (international reserves, exports, terms of trade, deviation of the real exchange rate from tend, commercial bank deposits, output) the limit is below the mean, while for the other indicators, it is above the mean.

²⁷ The maximum percentage would be achieved if a signal was received in every month for every crisis.

last measure of the success of an indicator is a comparison between the probability of a crisis conditional on a signal from the indicator and the unconditional probability of a crisis.²⁸

The "lead-time" or number of months in which a particular indicator produces its first warning signal before a crisis was acceptable for all 15 indicators examined. Signals began between 12 and 18 months before a crisis on average. The longest lead-time of 17 months belonged to the real exchange rate and real interest rates, which again confirms the exceptional predictive power of the real exchange rate variable in signaling crisis.

The last criterion the authors discuss is the persistence of early warning signals.²⁹ The authors found that, for the majority of indicators, signals were sent in the pre-crisis period at least twice as frequently as in tranquil times. The only exception was the real exchange rate, for which the signal in pre-crisis times was more than five times as frequent as in normal economic conditions.

Finally, the authors suggest that a successful warning system requires the processing of a large amount of information and the monitoring of the behavior of numerous economic indicators. They argue that countries in the sample should put their attention on variables that have proven to be the most reliable in predicting crises in the past 25 years. Those indicators are as follows: 1) international reserves, 2) real exchange rate, 3) domestic credit, 4) credit to the public sector and 5) inflation rate.³⁰

²⁸ *The conditional probability is greater than the unconditional probability only for effective and useful indicators.*

²⁹ *This is a simple inverse of the noise-to-signal ratio expressing the existence of a signal in the pre-crisis period relative to a "peaceful" period.*

³⁰ *Certain additional indicators should not be ignored, although their success measures were lower (trade balance, exports, money supply growth, real GDP growth, fiscal deficit).*

3.2 The "signals" approach to twin crises - transition countries

The "signals" approach was applied to the sample of transition countries in Bruggemann and Linne (1999). The study covered Russia, the Czech Republic, Hungary, Bulgaria and Romania during the years 1991 to 1998. Data availability and the fact that these countries experienced serious financial problems during the observed transition period influenced the choice of countries in the sample.

The authors are most interested in whether all the countries studied shared some common macroeconomic features that led to the currency or banking crises. They begin with an analysis of events in each country separately, following the behavior of indicators before and after the currency or banking crisis, with the aim of identifying the vulnerability of the economies studied.

Table 3

EVENTS CHARACTERIZING "TWIN" CRISES IN TRANSITION COUNTRIES

	BANKING CRISIS	CURRENCY CRISIS
Czech Republic	August 1996 Closing of 8 banks	May 1997 After 10 days of speculative attacks, the fixed exchange rate system was abandoned
Russia	August 1998 Big jump of interest rates Growth of share of short-term debt in total foreign debt Bank closures	August 1998 Devaluation of the ruble, change to a fluctuating exchange rate regime
Bulgaria	March 1996 Failure of the agricultural bank and beginning of the process of closing almost half of the banks in the banking system	January 1997 Introduction of currency board after a period of hyperinflation
Hungary	December 1993 "Bad" loans reach almost 20% of total	December 1994 Introduction of urgent savings measures as current account deficit reaches 9.4% of GDP
Romania	December 1996 "Bad" loans reach 39% of total, and end up at 57% in 1997	January 1997 Romanian lei devalued by 20% in one week

Source: Bruggemann and Linne (1999).

In defining crises, the authors pass over the K-L-R approach to constructing an index of the foreign exchange market pressure as a measure of currency crisis. Instead, they focus only on events that describe currency and banking crises. Table 3 display the events that the authors marked as the beginning of banking or currency crises in the transition economies studied. These events formed the basis of their tests of the usefulness of signal approach in these specific conditions.

In the pre-crisis and post-crisis period, 16 economic and financial variables were analyzed. The data were obtained from the national statistics of the countries studied. The variables are divided below into groups representing key areas of economic life with signs that express the theoretical presumptions about their behavior in a pre-crisis period:

I Fiscal variables

The budget deficit/GDP, nominal (+) - although this variable most often grows before currency crisis, this is not necessarily the case before banking crises. The presumption is that this indicator may grow after banking crises because of the high costs of programs to help (rehabilitate) banking systems.

II Monetary variables

M2 multiplier (+) - it is presumed that both kinds of crisis are closely connected to the growth of the domestic banking system, which is aided by financial liberalization. This leads to decreased reserve requirements and growth in the money multiplier.

Domestic credit/GDP, nominal (+)-credit expansion follows financial deregulation and cyclical "overheating". It precedes banking and currency crises. After a currency crisis, credit activity decreases sharply, banks become more cautious, and total economic growth slows.

Bank deposits (-)-this expresses a run on banks, a main indication of a banking crisis. Decreases in bank deposits indicate a loss of confidence in the health of the banking system before banking crises.

III Current account

Exports (-)-currency crises often are closely correlated with overvalued real exchange rates in the pre-crisis period. Therefore, exports is to be expected to fall in this period; decreased competitiveness and increased business failures put further pressure on the banking system.

Imports (+)-theoretical presumptions are not entirely clear (sometimes contradictory) in this area. Appreciation stimulates imports, but decreases in exports lead to slower economic growth and decrease import demand.

Real exchange rate (-)-banking crises can occur because of strong appreciation that hinders competitiveness and makes foreign loans expensive.

IV Capital account

International reserves in US dollars (-) - it is expected to fall before a currency crisis because of monetary authority's measures to defend the exchange rate. However, a fall may also be expected in a banking crisis. This variable is a traditional measure of an economy's ability to finance imports.

M2/international reserves (+)-this variable is expected to rise before financial crises (resident increasingly convert domestic money into foreign).

Real interest rate differential (+) - a sharp increase is to be expected in banking as well as in currency crises as a measure to stem capital flight

Foreign debt (+)-this variable is "dangerous" if financial markets believe that the foreign debt is unsustainable.

Short term foreign debt (+) - an increase in short term debt points to rising difficulties in rolling over foreign debt due to the increased risk; excessive exposure to financial markets leads to an increased vulnerability of macroeconomic situation.

Capital flight (+)- this variable is closely related to decreases in bank deposits, since usually it is domestic residents who are the first to anticipate impending crises. Increased capital flight can intensify a currency crisis, and can further deepen a banking crisis.

V Economic growth

Output (-)-an overvalued exchange rate and a fall in exports decrease economic activity before the beginning of a banking or currency crisis. While the effect of a recession on a currency crisis is direct, in the case of a banking crisis the effect is indirect (via the overvalued exchange rate, which lowers marginal profits, worsening credit portfolios of banks).

Real domestic interest rates (+)-high interest rates may be sign of liquidity problems, disturbances in the banking system or recession.

Lending/deposit interest rates (+)-This variable expressed the fall in the "quality" of loans. Deterioration in the credit portfolio may occur because of negative selection and moral hazard.

The authors use various numbers of months for the signal horizon in analyzing these variables. Signals emitted within the 18 months before a crisis are considered good signals. In the case of banking crises, the analysis does not stop with the beginning of the crisis, but continues in the post-crisis period. A signal of banking disturbances is considered reliable if it occurs in the 9 months before the crisis or the 9 months after the start of the banking crisis.

Estimates of the usefulness of each indicator are made using the matrix. First, it is necessary to determine the critical value that separates sustainable from unsustainable behavior of the indicator. When the optimal critical value is established for all the observations of a single indicator, that value is used as a specific critical value applicable only to that particular variable and that particular country.³¹

Results of the analysis for the transition countries

The authors found a set of indicators providing early warnings of currency and banking crises in transition countries. For the whole sample, the best signal indicator was exports with the adjusted noise-to-signal ratio of 0.12 for currency crises and 0.24 for banking crises. Those variables with the ratio above one were excluded: imports, interest rate differentials, world interest rates and capital flight. Furthermore, in transition countries studied, Kaminsky's (1998) statement that a substantial growth in foreign debt and strong capital inflows usually precede crises was only partially confirmed. The results show that "liquidity" is more important in currency crises in transition countries than elsewhere. "Liquidity" is defined as the share of short-term debt in total foreign debt, and has a noise-to-signal ratio of 0.24.

The authors were very aware of the problem of twin crises, concluding that it is much more difficult to anticipate banking crises than attacks on the currency. The mean value of the noise-to-signal ratio for all indicators considered for all five countries was 0.75 for banking crises and 0.59 for currency crises (calculated on the basis of the data from Table 4). However, it must be taken into account that the results for banking crises are strongly influenced by the behavior of imports and world interest rates with very high values of the ratio.

³¹ For example, it is possible to establish that the limit that minimizes the measure of false signals for all observations of the current account balance of various countries at 12 percent. Then all monthly observations above this boundary are used as signals of crisis. However, it is necessary to be especially cautious here, since a current account deficit of 4 percent may be a problem for one country, and not for other countries in the sample.

Therefore, the authors measure the median value of the noise-to-signal ratio instead of the average, and this gives a completely different picture. The medium value of the ratio of all indicators is 0.30 for banking crises and 0.49 for currency crises. It is evident that a large number of the indicators relating to the domestic financial system in fact fulfill the authors' expectations, since they provide strong and accurate signals of banking crises. Bank deposits, the money multiplier and the share of domestic credit in GDP provide especially useful signals.

Table 4

THE ADJUSTED NOISE-TO-SIGNAL RATIO -TRANSITION COUNTRIES

INDICATOR	CURRENCY CRISIS	BANKING CRISIS
Budget deficit/GDP	0.13	0.30
M2 multiplier	0.94	0.69
Domestic credit/GDP	0.36	0.30
Bank deposits	0.25	0.12
Exports	0.12	0.24
Imports	1.70	2.77
Real exchange rate	0.37	0.53
Foreign exchange reserves	0.31	0.24
M2/reserves	0.33	0.35
Real interest rate differential	1.05	0.14
World interest rate	1.08	4.80
Foreign debt	0.63	0.33
Capital flight	1.26	0.95
Short-term foreign debt	0.24	0.16
Gross domestic product	0.69	0.28
Real interest rates	0.60	0.80
Lending/deposit interest rates	0.13	0.25

Source: Bruggemann and Linne (1999, p. 15).

The currency crisis in the *Czech Republic* was preceded by numerous signals. Almost 80 percent of the indicators tested sent signals at various time lags within 18 months before the currency crisis. Although the behavior of these variables worsened considerably within this period, the majority of them did not pass the critical degree of deviation from trend. About 40 percent of the indicators sent signals half a year before and 56 percent four months before the crisis. It seems that the crisis occurred because of worsened domestic economic conditions and not, for example, because of the influence of the Asian crisis. They conclude this because imports, foreign debt, real interest rates and capital flight did not send any signals in the pre-crisis period. After the currency crisis in May 1997, the majority of the variables observed returned within normal bounds far from their critical values. The exception was bank deposits, which stayed in the critical area, increasing worries about the Czech banking system.

The hyperinflationary period in *Bulgaria* affected almost all variables strongly. However, signals were much weaker than in the Czech Republic. Although the deterioration in economic conditions was noted in all variables, none of the variables crossed their critical values. The budget deficit, domestic credit and international reserves sent the strongest signals, and domestic interest rates, imports and the foreign debt sent the weakest signals. In Bulgaria, unlike the Czech Republic, some indicators continued to give warning signals even after the crisis. Exports and gross domestic product fell and domestic credit rose.

Hungary was, along with Romania, the country with least useful indicators signaling BOP difficulties and banking problems. Surprisingly, exports and the real exchange rate did not provide signals. Hungary was unique in that its imports, contrary to all expectations, played the role of a signal indicator. In addition to imports, the useful warning indicators were the growth of credit, the share of short-term debt in total foreign debt, interest rate differentials and bank deposits. Even after the crisis year of 1994, interest rate differentials did not return to their normal range. This does not necessarily represent a great danger, since Hungary has large capital needs. During 1998, domestic credit again rose sharply. This could be the sign of a new cycle of prosperity or a cyclical "overheating".

Among the transition countries studied, *Romania* had the least number of indicators with signaling power. Only five of the total number of variables produced signals in the pre-crisis period: industrial production, deficit/GDP, exports, real exchange rate and M2 multiplier. However, these variables did not return to their normal range after the crisis, although signals were weaker than in 1996.

In analyzing the *Russian* economy, as many as nine indicators were found with satisfactory signaling properties suggesting that the Russian crisis was mainly the result of domestic disturbances and weakened economic conditions, rather than the effect of the Asian crisis. Real exchange rate, deficit/GDP, exports, domestic credit, reserves and M2/reserves were a complex of variables that provided a good picture of the state of the Russian economy even in the first nine months of 1998.

The authors considered these results quite heartening, since they show that transition countries, despite their specifics, share numerous common characteristics with other market economies. Analyzing the behavior of signaling indicators in transition economies, the authors conclude that currency and banking crises in these countries were not the effect of "contagion" (the spill-over effect of crises in other areas) but mainly "domestic" in character. The authors argue that the Russian crisis was a twin crisis; the Czech crisis was mainly a currency crisis,

and the Hungarian crisis mainly a banking crisis. They are aware that their research has its limitations³², since the classification of crisis and the separate analysis of currency and banking crisis is still an area open for discussion. Although there have not been many empirical tests of this very young method, the "signals" approach has shown its usefulness in studying the development of an early warning system for possible economic disturbances. In this way, policymakers would have information on which to base prompt policy changes to perhaps eventually avoid economic crises.

4

HOW EARLY WARNING SYSTEM OF CURRENCY AND BANKING CRISES WORKS IN CROATIA?

The empirical tests of the "signals" method used in transition countries cannot be applied to the Croatian case uncritically. There is still not enough empirical experience in the application of the method. Above all, the time horizon is too small. In Croatia, it is even smaller than in other transition countries, since it only includes the post-stabilization period.

4.1 Defining banking and currency crisis in Croatia

The first step in applying the "signals" approach is to identify the important events, whether relating to the currency or banking sector in Croatia in the period January 1995-May 1999. There was no real currency crisis in Croatia in that period. This can be seen from the *Croatian index of foreign exchange market pressure*, calculated according to the KLR signaling approach (Figure 1). Since we have inverted the exchange rate variable, *in our case the index of pressure decreases due to depreciation of the domestic currency. It also decreases when international reserves (in US dollars) fall.* Even using a criterion³³ of one standard deviation from the mean, the index of exchange market pressure does not indicate

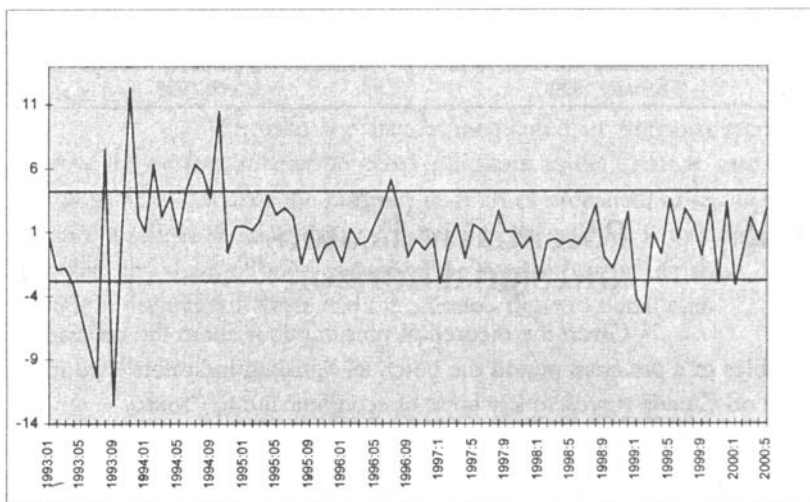
³² *The newness of the signaling approach and the problems of small samples apply to this study of only five transition countries.*

³³ *The use of the criterion of three standard deviations would leave us without any reference events during the period that we could characterize as a currency disturbance.*

a currency crisis in the referent period, since a crisis must end in a substantial devaluation or a change in the exchange rate regime. Instead, we see a mild currency disturbance culminating at the beginning of 1999. However, that disturbance can be considered a "crisis" for analytical purposes, to facilitate the search for early warning indicators of the foreign exchange market pressure of January-February 1999.

Figure 1

**INDEX OF
FOREIGN
EXCHANGE
MARKET
PRESSURE
IN CROATIA**



A banking crisis began in March 1998 with the failure of Dubrovačka banka, the fifth biggest bank in Croatia by size, with a share of 5 percent in total banking assets. The decision on the rehabilitation of the bank was made in April 1998. In July 1998, Dubrovačka was joined by Glumina banka (sixth by size with a 3 percent share in total banking assets). While the possibility of rehabilitation of Glumina banka was rejected by the Croatian National Bank in September 1998, bankruptcy proceedings were not opened until March 1999. By the end of 1998, Županjska banka (2 percent share), Komercijalna banka, and Gradska banka Osijek (seventh in size, 2 percent share) failed. These banks went into bankruptcy in March 1999.³⁴ In January 1999, Croatia banka (2 percent of total banking assets) went into crisis, and in the same month the Croatian National Bank introduced a new liquidity loan collateralized by long-term government securities for a group of "crisis" banks. In mid 1999, 1.1 billion HRK (HRK - Croatian kuna) of liquidity loans were outstanding, representing 12 percent of base money.

³⁴ In addition to these banks, some smaller banks and savings banks failed: Neretvansko-gospodarska banka, Građanska štedionica Karlovac, Ilirija banka and Invest štedionica.

The Croatian case conforms to the pattern that banking crises precede currency crises, last longer than currency crises and peak months after the failure of the first bank. In Croatia, the banking crisis began almost a year before the currency disturbance, during the beginning of a recession, and reached its peak at the end of 1998 and the beginning of 1999. The reference events for using the method in Croatia are therefore:

Currency "Crisis"	Banking Crisis
February 1999	March 1998

4.2 Potential indicators and signal horizon

Given the theoretical presumptions about the behavior of variables in a pre-crisis period the potential signaling indicators used in the study on Croatia represent key areas of economic life in Croatia:

1. *Bank deposits, total (deposits at commercial banks, calculated as M4 minus currency in circulation)*
2. *Total domestic credits (commercial bank claims on other domestic sectors, other banking institutions and other financial institutions)*
3. *M4 multiplier (M4/M0)*
4. *M4/foreign assets of the Croatian National Bank (CNB)*
5. *Commercial bank loans to enterprises*
6. *Commercial bank loans to household*
7. *CNB claims on central government (HRK and foreign exchange loans and matured claims on the government budget)*
8. *Exports, total, US dollars*
9. *Imports, total, US dollars*
10. *Real effective exchange rate (calculated via consumer prices)*
11. *International Reserves, US dollars*
12. *Foreign debt, total, US dollars*
13. *Short-term foreign debt*
14. *Budget deficit*
15. *Industrial production, total*
16. *Gross domestic product, quarterly, 1990 prices (extrapolated to monthly data)*
17. *Real domestic interest rates (interest rates on the Zagreb Money Market minus the annual rate of change of consumer prices)*
18. *Lending/deposit interest rates ratio (interest rates on HRK loans and deposits not indexed to foreign exchange).*

The observation period extends from 1994 to the first half of 1999. The series are expressed as annual growth rates (with the exception of budget deficit, interest rates and exchange rate). For the currency crisis, the signal horizon is 18 months before the disturbance. Signals emitted in that period are considered reliable.³⁵ In tranquil times, every signal indicating a disturbance is considered false. For banking crisis, the signal horizon is mainly limited to 12 months before the failure of the first bank. Because of the nature of the banking crisis, monetary variables are monitored even after this crisis event.

We used the matrix mentioned in previous section to analyze the performance of potential indicators. In the Croatian case, it was not possible to calculate the percentage of crises predicted, since this would require a longer series and more than two crisis events. It was possible to calculate the share of good signals in the signal horizon, the share of false signals in the tranquil times and the adjusted noise-to signal ratio.

4.3 The most successful signal indicators for "twin" crisis in Croatia

The results of the initial research efforts to find an early warning system for banking and currency crisis in Croatia are shown in Tables 5 and 6. On this basis, I will draw some conclusions about the possibilities and limits of using this method for Croatia.

The key measure in choosing the most successful indicators was the adjusted noise-to-signal ratio. All variables with the ratio greater than one were excluded from the list. The choice should also depend on the lead-time of each indicator, since it is important whether the variable warns of a crisis one-month or many months ahead.

³⁵ A signal horizon of 24 months was used for the variables: total credits, M4 multiplier, M4/CNB foreign assets, imports, exports, international reserves, real domestic interest rates.

Table 5

SUCCESS OF INDICATORS IN SIGNALING CURRENCY CRISIS - CROATIA

INDICATOR	% good signals A/(A+C)	% false signals B/(B+D)	noise-to-signal ratio [B/(B+D)]/[A/(A+C)]	lead-time	persistence of signal*
Bank deposits	83.3	22.6	0.27	17	3.70
Total credits	37.5	35.0	0.93	24	1.07
M4 multiplier	45.8	36.0	0.79	20	1.27
M4/ CNB foreign assets	33.3	40.0	1.20	23	0.83
DMB's loans to enterprises	37.5	35.0	0.93	24	1.07
DMB's loans to households	41.7	30.0	0.72	24	1.39
CNB claims on central government	50.0	16.0	0.32	15	3.13
Exports	41.7	35.1	0.84	17	1.19
Imports	37.5	40.5	1.08	22	0.93
Real exchange rate	50.0	20.0	0.40	18	2.50
International reserves	50.0	37.5	0.75	21	1.33
Foreign debt, total	38.9	25.0	0.64	17	1.56
Short-term foreign debt	55.6	12.5	0.23	18	4.35
Budget deficit	50.0	20.9	0.41	9	2.44
Industrial production	55.6	35.5	0.64	9	1.56
Gross domestic product	61.1	32.3	0.53	17	1.89
Real domestic interest rate	45.8	20.0	0.44	21	2.27
Lending/deposit interest rate ratio	61.1	25.8	0.42	15	2.38

DMB - domestic money banks, commercial banks

*The persistence of a signal is the simple inverse of the noise-to-signal ratio and expresses the persistence of a signal in the pre-crisis period relative to "normal" times.

Table 6

SUCCESS OF INDICATORS IN SIGNALING BANKING CRISIS - CROATIA

INDICATOR	% good signals A/(A+C)	% false signals B/(B+D)	noise-to-signal ratio $[B/(B+D)]/[A/(A+C)]$	lead-time	persistence of signal*
Bank deposits	94.4	24.0	0.25	7	4.00
Total credits	83.3	28.6	0.34	12	2.94
M4 multiplier	50.0	41.4	0.83	9	1.20
M4/ CNB foreign assets	66.7	38.1	0.57	12	1.75
DMB's loans to enterprises	50.0	33.3	0.67	12	1.49
DMB's loans to households	75.0	28.6	0.38	12	2.63
CNB claims on central government	33.3	17.2	0.52	4	1.92
Exports	33.3	39.5	1.18	6	0.85
Imports	41.7	39.5	0.95	9	1.05
Real exchange rate	77.8	20.7	0.27	8	3.70
International reserves	52.2	33.3	0.64	12	1.56
Foreign debt, total	55.6	33.3	0.60	6	1.67
Short-term foreign debt	77.8	16.7	0.21	7	4.76
Budget deficit	22.2	21.9	0.99	5	1.01
Industrial production	33.3	37.9	1.14	3	0.88
Gross domestic product	66.7	31.0	0.47	6	2.13
Real domestic interest rate	41.7	27.0	0.65	10	1.54
Lending/deposit interest rate ratio	66.7	24.1	0.36	4	2.78

DMB- deposit money banks

*The persistence of a signal is the simple inverse of the adjusted noise-to-signal ratio and expresses the persistence of a signal in the pre-crisis period relative to tranquil times.

Imports, M4/CNB's foreign assets, total credits, and commercial bank loans to enterprises were excluded from *the list of signaling indicators for currency crisis*. Within the other fourteen variables, there are great differences between the better and the inferior warning variables. *The most successful indicators for warning about the Croatian currency disturbance* in February 1999 (with the noise-to-signal ratio in parenthesis) are:

- 1) *Bank deposits (0.27)*
- 2) *CNB claims on central government (0.32)*
- 3) *Real exchange rate (0.40)*
- 4) *Short-term foreign debt (0.23)*
- 5) *Budget deficit (0.41)*
- 6) *Domestic real interest rates (0.44)*
- 7) *Lending/deposit interest rate ratio (0.42)*

As for other transition countries, short-term foreign debt, and not total foreign debt provided a stronger signal. This is not necessarily worrisome, since Croatia is only slightly exposed to the world foreign exchange market and the share of short-term debt in total foreign debt is low. The majority of variables studied (except for the budget deficit and industrial production) had long lead-times. The first signals were sent at least 15 months before the currency crisis. After the disturbance in February 1999, most of the indicators settled down to their normal levels well below the critical value. The budget deficit was an exception, continuing to grow in nominal terms and sliding towards its critical value. The continued decrease in bank deposits after February 1999 should be taken with reserve, since monetary statistics excluded four banks in bankruptcy in May 1999, resulting in falls in most monetary aggregates.

Although the authors who studied signaling indicators in transition countries had trouble anticipating banking crises, the same cannot be said for Croatia. Fourteen indicators were found with adequate predictive power, and only exports, imports, the budget deficit and industrial production did not have predictive power. *The best warning indicators of the banking crisis that began in March 1998* (with noise-to-signal ratio below 0.5) are the following:

- 1) *Bank deposits (0.25)*
- 2) *Total credits (0.34)*
- 3) *Commercial bank loans to households (0.38)*
- 4) *Real exchange rate (0.27)*
- 5) *Short-term foreign debt (0.21)*
- 6) *GDP, extrapolated monthly (0.47)*
- 7) *Lending/deposit interest rate ratio (0.36)*

In addition to monitoring these indicators within the signal horizon, it is interesting to follow their behavior during the banking crisis that extended through the second half of 1998 and culminated at the beginning of 1999. Total credits grew rapidly for almost twelve months before the failure of the fifth bank by size Dubrovačka banka. In the second half of 1998, the series stopped providing a signal, returning to normal values far from the critical value. However, bank deposits showed a downward trend months after the failure of the first bank. The real exchange rate began to slide (appreciate) towards the critical value almost eight months before the banking crisis. This makes it one of the best indicators of banking problems. Contrary to expectations, domestic real interest rates behaved more like a coincident than a leading indicator. It rose rapidly during the banking crisis all the way to the currency "crisis" in February 1999. The same can be said for international reserves, which began to fall after the failure of the first bank. Loans to households and short-term foreign debt provided good signals only within the signal horizon and returned to their normal range rapidly after the Dubrovačka banka failure.

At the end of the analysis, a logical question arises: which disturbance do the indicators warn of best? The mean value of the noise-to-signal ratio of all indicators is 0.64 for currency and 0.61 for banking crisis. As in the preceding study, it would be better to calculate the median value to exclude the influence of variables with extremely high rates of noise. The median value of the noise-to-signal ratio of all indicators was 0.64 for currency crisis and 0.58 for the banking crisis. Three variables relating to the domestic financial system such as bank deposits, total credits and loans to households signaled the banking crisis very accurately and promptly, as would be expected.

5

CONCLUDING REMARKS - SHOULD WE BE SATISFIED WITH THE SYSTEM OF SIGNALING INDICATORS?

The number of signaling indicators that proved useful and accurate in predicting a banking crisis and a smaller currency disturbance in Croatia exceeded all our expectations. There were many limitations placed upon the inquiry by the newness of the method and the availability of data. First, we abstract from the fact that Croatia did not experience a true currency crisis resulting in a major devaluation or change in exchange rate regime. Because of this, we considered the movements in the Croatian index of the foreign exchange market pressure to pass the critical bound in January and February 1999 for analytical purposes, even though the disturbance was actually mild.

The analysis was also burdened by the fact that there were too few crisis events during the period studied to base a fully effective crisis early warning system. On the other hand, it is quite heartening that many of the variables studied in the pre-crisis (and post-crisis) period behaved in harmony with theoretical expectations presented in this paper.

The banking crisis in Croatia began in March 1998 and continued through the beginning of 1999. The indicators which were most useful in anticipated events in the banking system were: bank deposits, total credits, loans to households, real exchange rate, short-term foreign debt, GDP and lending/deposit interest rates. The behavior of the majority of variables in early 1999 indicates that the situation in the banking system is calming down, and the variables are returning to their normal range. This is in accordance with theoretical presumptions that a currency disturbance usually occurred months after the first bank failure. The currency disturbance in fact happened almost a year after the first major events in the banking system. In the second half of 1998, the whole economy went into recession, with the banking crisis continuing to build and culminating at the beginning of 1999. The best indicators of currency crisis were bank deposits, credit to the public sector, the real exchange rate, short-term foreign debt, budget deficit, domestic real interest rates and the relation between domestic lending and deposit interest rates.

Despite all the limitations in the use of the "signals" method mentioned above, we can be fairly satisfied with the results of our search for an early warning system for Croatia. It further heartens us that the results of this analysis do not differ significantly from those obtained on the sample of transition

countries. However, we must be aware that we are only at the beginning of a serious empirical task whose final goal is to build an effective early warning system for currency and banking crisis in Croatia. The first step has been made to use a very new method, so the group of indicators analyzed here can be seen as a basis for further research. The ultimate goal is to uncover better and better warning information that will allow policymakers enough maneuvering room to avoid or at least minimize the negative consequences of future currency and banking crisis in Croatia.

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APPENDIX 1

POTENTIAL LEADING INDICATORS OF CURRENCY CRISIS

<p>A. CAPITAL ACCOUNT <i>International reserves</i> <i>Capital flows (short-term)</i> <i>Foreign direct investment</i> <i>Differences between domestic and foreign interest rates</i></p> <p>B. FOREIGN DEBT <i>Total foreign debt</i> <i>Foreign debt of the public sector</i> <i>Maturity structure (short-term foreign debt)</i> <i>Origin (creditors) of foreign debt and interest rates</i> <i>Projection of repayment of principal and interest</i> <i>Various forms of foreign aid</i></p> <p>C. CURRENT ACCOUNT <i>Real exchange rate</i> <i>Current account balance</i> <i>Trade balance</i> <i>Exports</i> <i>Imports</i> <i>Terms of Trade</i></p> <p>D. INTERNATIONAL VARIABLES <i>Real GDP growth in trading partners</i> <i>Foreign interest rates</i> <i>Price level</i></p> <p>E. FINANCIAL LIBERALIZATION <i>Credit policy</i> <i>Changes in the money multiplier</i> <i>Real domestic interest rates</i> <i>Difference between lending and deposit interest rates</i></p> <p>F. FISCAL VARIABLES <i>Budget deficit</i> <i>Government expenditure</i> <i>Credits to the public sector</i></p>	<p>G. OTHER FINANCIAL VARIABLES <i>Central bank credits to commercial banks</i> <i>Gap between demand and supply of money</i> <i>Growth of money supply</i> <i>Rate of return on bonds</i> <i>Rate of inflation</i> <i>“Shadow” exchange rate</i> <i>Average exchange rate</i> <i>M2/international reserves</i></p> <p>H. REAL SECTOR <i>Real GDP growth</i> <i>Employment/unemployment</i> <i>Growth of wages</i> <i>Price of inventories</i></p> <p>I. INSTITUTIONAL AND STRUCTURAL VARIABLES <i>Openness</i> <i>Market concentration</i> <i>Degree of control of exchange rate</i> <i>Duration of fixed exchange rate system</i> <i>Degree of financial liberalization</i> <i>Size and health of the banking system</i> <i>Intensity of previous crises and currency disturbances</i> <i>Changes on the foreign exchange market (devaluation, revaluation, changes in exchange rate system, unsuccessful speculative attacks...)</i></p> <p>J. POLITICAL VARIABLES <i>Elections</i> <i>Elections defeats or victories</i> <i>Changes in government</i> <i>Changes in minister of finance</i> <i>Representation of left-wing parties in government</i> <i>Degree of political (in)stability</i></p>
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Source: Kaminsky, Lizondo and Reinhart (1997).

APPENDIX 2

THE PERFORMANCE OF INDICATORS - THE "SIGNALS" APPROACH

INDICATOR	% of crises*	% good signals	% false signals	noise-to-signal ratio	lead-time	persistence of signal*
		A/(A+C)	B/(B+D)	$[B/(B+D)/A/(A+C)]$		
Real exchange rate	57	25	5	0.19	17	5.14
Exports	85	17	7	0.42	15	2.37
Share prices	64	17	8	0.47	14	2.15
M2/international reserves	80	21	10	0.48	13	2.07
Index of production	77	16	8	0.52	16	1.93
Monetary equilibrium	61	16	8	0.52	15	1.92
International reserves	75	22	12	0.55	15	1.82
Money multiplier (M2)	73	20	12	0.61	16	1.64
Credit/GDP	56	14	9	0.62	12	1.62
Real interest rates	89	15	11	0.77	17	1.30
Terms of trade	79	19	15	0.77	15	1.29
Real interest differential	86	11	11	0.99	14	1.01
Imports	54	9	11	1.16	16	0.86
Deposits	49	16	19	1.20	15	0.84
Lending/deposit interest rates	67	13	22	1.69	13	0.59

Source: Kaminsky, Lizondo and Reinhart (1997).

* Percentage of crisis predicted by at least one signal in the 24 months preceding the crisis.