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# Currency Crisis: Theory and Practice with Application to Croatia

CROATIAN NATIONAL BANK

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The opinions presented in the paper are those of the author and are not necessarily identical to those officially held by the Croatian National Bank.

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**Summary**

Following an initial overview of theoretical and empirical currency crisis models, the paper presents an early warning system of a currency crisis in Croatia, based on two standard empirical methods of researching and forecasting a currency crisis: the signalling method and the probit model. Measuring the index of exchange market pressure has so far indicated two currency crises in Croatia: one in September 1998 and the other in August 2001. The signalling method was used for the purpose of selecting the determinants of a currency crisis (in the period from January 1996 to March 2003) from a wide range of variables that are considered the best predictors of currency crises in the period of 12 months preceding them: the share of public finances in GDP, the share of the current account balance of the balance of payments in GDP, inflation, the share of freely available bank reserves in total bank assets, the rate of external debt growth, the rate of growth of the m2 multiplier, the deviation of the real exchange rate from the trend, the share of the foreign exchange assets of CNB in M4, and the growth of domestic credit. The currency crisis composite index, expressed as a weighted average of all the previously listed currency crisis indicators, shows a considerable predicting power of currency crisis in the sample. The statistically more rigorous probit model method exposes five variables among the indicators of vulnerability, of various forms of functional specification, that best empirically describe the characteristics of the periods preceding the two currency crises in Croatia. Thus there is a real exchange rate appreciation that is below the trend, a decrease in the share of the balance of public finances in GDP, a decrease in the share of the current account balance of the balance of payments in GDP, an increase in inflation and an increase in external debt, which increase the probability of a speculative attack on the kuna. As is the case with the composite indicator, the various goodness-of-fit measures of the customised probit model used in the Croatian example indicate a very high level of predicting power regarding the currency crisis in the sample. A more detailed analysis of each of the currency crisis indicators leads to the conclusion that the two currency crises in Croatia were not of the same nature. The indicators of the first crisis can be found in the literature on the third generation currency crises which describes the correlation between banking system difficulties and the currency crisis, while the signalling variables of the second crisis can be linked to the self-fulfilling characteristics of the second generation models of currency crises.

**JEL**: F31, F47

**Key words**: currency crisis, early warning system, signalling method, probit model, Croatia

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## 1 Introduction

There is general consensus among economists that an early warning system, regardless of how highly technically advanced it is, cannot be fully successful in forecasting a currency crisis. Economic losses, however, that are the consequence of a currency crisis [fiscal and quasi-fiscal costs of restructuring the financial sector, a fall in economic activities, distortions in income distribution, a fall in credibility (IMF, 1998)] stress the importance of crisis prevention and the use of all the available tools that can contribute to the early recognition of financial system vulnerability to a currency crisis. Therefore it is desirable to have some kind of mechanism or system that can recognize indicators of vulnerability and forecast a pending currency crisis in order to enable the timely introduction of measures that avert the crisis.

Over the last fifteen years, various theoretical currency crisis models have been developed with the aim of explaining distortions in financial systems or the collapse of a currency regime. At the same time, there has been an explosion in empirical analyses attempting to signal, i.e. forecast, a currency crisis. By applying the theoretical insight into currency crises to the evaluation of existing theoretical models, it should be possible to use empirical models to forecast a currency crisis, particularly if certain regularities appear in the occurrence of currency crises. In order to discover these regularities, but also because of the relatively small number of currency crises in individual countries, most empirical papers focus on panel analyses which include experiences gained from currency crises in various countries and, as is lately the case, in similar countries. Theoretical literature, however, offers no consensus on the causes of currency crises. Since different models (different "generations" of models) identify different factors as the causes of a crisis, and since individual countries show considerable deviations from each "generation's" variables of currency crisis models, the advantage of empirical studies of individual countries is evident.

The development of specific econometric tools for explaining and forecasting currency crises in recent years has enabled the testing of theoretical models and currency crisis determinants and the development of early warning systems specific to individual countries. Systems based on determinants specific to a single country have the advantage that the findings do not reflect the generalizations and "abstract" models for a universal currency crisis but are based on factors specific to the country in question. Analysis based on a single country allows a more meaningful comparison of findings with theoretical models as well as the option of changing certain determi-

nants of a particular theoretical model for the purpose of better understanding this country's currency crisis. In addition, an *ex post* comparison of the characteristics and findings of the country-specific empirical model with the circumstances prevailing in the economic system in the course of (and before) the onset of a currency crisis does not have to deal with the problems normally seen when the analysis deals with currency crises in a number of countries. This is because a cross-country analysis makes it difficult to interpret the findings with respect to a single country since the findings obtained are the result of generalization.

The backbone of an early warning system is an empirical model, which includes a number of selected economic indicators. The values of these indicators are usually different before, during and after a crisis, so their movements can be used to forecast the probability of the onset of a crisis. The aim of this paper is to construct such an early warning system. The system should provide a satisfactory way of selecting indicators preceding a currency crisis and thus anticipate the actual crisis. Assuming a high degree of probability that the same indicators signal the possible occurrence of another crisis, the system should provide valuable support to economic policy management.

Due to the well-known problems concerning data from the pre-stabilization period in Croatia and immediately following the stabilization period, this analysis encompasses the period from 1996 to the first quarter of 2003. Based on the crisis definition used in empirical literature, two currency crises have been identified in the period under review. Within the methodological framework selected, two different models have been applied for the purpose of explaining from an empirical standpoint the currency crises in Croatia, and the indicators have been identified that are considered to signal a currency crisis in a satisfactory manner. Thus an early warning system that includes two different empirical models and the information provided by the indicators can provide useful analytical guidance in creating economic policy.

To anticipate a currency crisis, it is necessary to understand its causes. This is why the first part of this paper presents theoretical insight into a currency crisis. This insight, adapted to the specific circumstances prevailing in Croatia, will provide a basis for empirical analysis. Exogenous variables will be taken from a number of theoretical models and will be used in the attempt to explain currency distortions present in Croatia. Section 3 will focus on experiences gained from various empirical research projects, as they enable understanding of the problems encountered in the process of testing theoretical insights. Section 4 presents an empirical analysis of currency crises in Croatia. The signalling method has been used to select indicators showing vulnerabilities in the financial system, and these indicators are later on used, in various functional forms, as independent variables in the probit model. The same part of the paper also covers statistical features of each method used in forecasting a currency crisis in the sample. Section 5 contains an interpretation of findings obtained by both methods of forecasting a currency crisis within the framework of circumstances prevailing in the Croatian economic system before the currency crises were identified. Section 6 of the paper provides concluding remarks.

## 2 Theoretical Models of Currency Crises

The theory of currency crises distinguishes between several crisis types according to their causes. Currency crisis literature describes three generations of models explaining the causes of currency crises.[1] The first generation ("speculative attack models") was created in an attempt to explain the currency crises in Mexico (1973-1982) and Argentina (1978-1981). These models indicate that an inadequate macroeconomic policy was the main cause of the currency crises. The second generation models ("exit clause models"), constructed so as to include the characteristics of speculative attacks in both Europe and Mexico in the 1990s, stress the self-fulfilling characteristics of a currency crisis and the occurrence of multiple equilibria. The third generation models stress the consequences of moral hazard to the banking system and the contagion effect as the key determinants of a currency crisis and use these same determinants to explain the currency crises in south-east Asia from 1997 to 1998. There are also numerous models dealing with single cases of crises, which represent alternative explanations of the causes of currency crises that are outside the conventional "generational directions".

### 2.1 Speculative Attack Models – First Generation Models of Currency Crises

Up to the early nineties, the intellectual framework regarding the understanding of currency crises was contained in the first generation models of currency crises, i.e. in the speculative attack model. Within the framework of this model, a currency crisis is seen exclusively as a sudden fall in the level of international reserves caused by an attack on the currency and the inevitable change in the exchange rate regime if the attack is successful. The impetus for a speculative attack is provided by an inconsistency between an expansive monetary and fiscal policy and a fixed exchange rate regime. Thus the currency crisis is actually the outcome of poor macroeconomic policy and of rational arbitrage by speculators.

The first formal model of a currency crisis presented in Krugman's paper (1979) provides the basic, intuitive insight into the first generation models of currency crises.[2] Krugman claims that a currency crisis is caused by a large budget deficit that is financed by credit expansion.[3] This will result in a gradual loss of international reserves. If there is equilibrium in the money market and if the interest parity condition is met under the fixed exchange rate (the domestic interest rate equals the one abroad), an expansion of credit results in a money supply that exceeds the demand for domestic currency (which will not change since the market does not expect a rate change at an early stage). The excess liquidity in the money market

1 Although most of the literature focuses on the explanation of currency crises of a fixed exchange rate system, a broader approach, which takes into account the possibility of attack on more flexible exchange rate regimes (as is the managed exchange rate regime in Croatia), has not had major impact on the change in the theoretical framework regarding the understanding of a currency crisis in the context of a fixed exchange rate (Garber, Svensson, 1994).

2 For a very detailed and technical overview of the first generation models, see Agenor, Bhandari, Flood (1991) and Garber and Svensson (1994).

3 The model assumes that the government is unable to incur debt in the capital market.

causes the market participants to increase the demand for foreign currency. In order to re-establish the equilibrium in the money market, the central bank is forced to sell its international reserves for domestic currency. Thus the level of international reserves gradually decreases over a period of time, at a rate equal to the domestic credit growth rate. Once the international reserves have been fully exhausted, the exchange rate regime has to be changed since the central bank has no more international reserves to maintain the fixed exchange rate regime.

Provided there are well-informed and rational speculators, an attack on the currency and the currency portfolio restructuring will be launched as soon as the market participants realize that they can expect a positive yield on their speculative move (Aziz, Caramazza, Salgado, 2000). Thus the international reserves do not decrease gradually over time but, when their level becomes low enough, there is a speculative attack and the speculators buy the remaining amount of international reserves, forcing the central bank to change the exchange rate regime. Although an inconsistency in macroeconomic policy[4] that dooms the exchange rate regime to fail can be recognised in advance, it is not profitable to attack the currency too early or wait with the attack for too long (Burda and Wyplosz, 2001). One of the major achievements of the first generation models is their ability to forecast the moment of speculative attack, when the international reserves suddenly fall to zero because the investors will not wait to see the collapse of the exchange rate regime through the gradual depletion of reserves.[5]

Due to the simplicity of Krugman's model, various additions have been made to it, including additional assumptions and characteristics of currency crises (low level of credibility of the exchange rate regime, sticky prices, uncertainty regarding a speculative attack, uncertainty regarding credit expansion, different exchange rate regimes, sterilization policy, alternative exchange rate regimes following the collapse of the current system, indebtedness in the foreign capital market and capital controls, wage contracts based on future expectations, endogenous economic policy) in order to bring the model closer to a real situation.[6] Each of the additions to the model stresses a single but different factor of currency crisis, which has proved important in empirical research of currency crises.

All the first generation models share one common and obvious flaw. The assumption regarding the passive stance of the government, i.e. that it will not do anything in spite of the fact that it knows the central bank has been losing international reserves and will therefore have to change the foreign currency regime, is not a realistic one. The thesis that a currency crisis is caused by a change in the basic macroeconomic variables makes its avoidance easy: measures need to be

4 It has to be stressed here that a good fiscal position is not a reason for excluding the possibility of a currency crisis. The fiscal balance may be a poor indicator of a government's contingent liabilities (e.g. collateralized deposits with banks). Once there are banking sector problems, the market participants, knowing that the monetary authorities will be forced to expand credit to cover the costs of banking sector rehabilitation, will attack the currency in the expectation of a currency depreciation.

5 For a detailed and technical overview of how to forecast the time of a speculative attack, see Blackburn and Sola (1993).

6 For a detailed overview of additions to the first generation models, see Garber and Svensson (1994). For a simple, non-technical overview, see Esquivel and Larrain (1998), Jeanne (1999), Dahel (2000) and Peltonen (2002).

introduced that bring these variables to a sustainable level, i.e. measures that are consistent with the maintenance of a fixed exchange rate regime.

## 2.2 Exit Clause Models – Second Generation Models of Currency Crises

The understanding of a currency crisis based on first generation models was questioned after 1992 due to their inability to explain the crisis of the European Monetary System (EMS) that happened in the same year. The problem underlying the EMS currency crisis was not just the economic policy of the EMS member countries, and the decision to change the exchange rate regime was not prompted by an inadequate level of international reserves (Dooley, 2000). The credibility of participation in the EMS, in France and Great Britain for example, was damaged by a combination of growing unemployment caused by the domestic economic situation and high interest rates caused by the situation created after the unification of Germany (Peltonen, 2002). These factors increased the costs of defending the exchange rate through higher interest rates and exposed the authorities to the temptation of introducing a more expansive monetary policy (Jeanne, 1999).

In order to explain the EMS crisis, new models of currency crises were developed, later described as second generation models of currency crisis or "exit clause models".[7] This generation of models saw the exchange rate regime as a conditional obligation – if a government decides to have a fixed exchange rate, it will keep it while it is considered useful (for instance, for the purpose of gaining anti-inflationary reputation and credibility). The obligation of maintaining a fixed exchange rate is limited by the existence of an exit clause, which allows the abandonment of the fixed exchange rate regime if the economic policy required for the purpose produces negative and unwanted effects on other economic variables. Thus the collapse of the European Exchange Rate Mechanism (ERM) was linked to the unwanted consequences that would arise from the necessary increase in interest rates to avert a successful speculative attack in an environment of high unemployment. In other words, the decision to abandon the exchange rate regime depends on the analysis of benefits (for example, benefits derived from the optimum currency area theory) and costs (for example, costs of decreased economic policy reputation) of maintaining the fixed exchange rate, given the economic situation (unemployment, banking sector difficulties, large public debt, etc.). Such circumstances are much closer to the real situation than are the first generation models, which assume the mechanical behaviour of authorities as opposed to the rational behaviour of market participants (Saqib, 2002). It is obvious that the economic policy options in a fiscal deficit situation go beyond to a simple monetization of the deficit. Since the goals of economic policy are multiple, all policy options include some form of *trade-off*, which makes economic policy endogenous (Aziz, Caramazza, Salgado, 2000). This "conditional nature" of macroeconomic policy, coupled with the fact that changes in the expectations of market partici-

7 For a detailed overview of the second generation currency crisis models, see Eichengreen, Rose, Wyplosz (1996).

pants regarding the future exchange rate have an impact on the trade-off, may result in multiple equilibria which make the speculative attack on a currency self-fulfilling (Saxena, 2001).

As opposed to the first generation models, second generation models do not assume determination, where causality goes exclusively from economic fundamentals to expectations. Causality in the second generation models can be followed in both directions, and it is precisely this kind of circularity that may result in multiple equilibria and self-fulfilling speculations (Jeanne, 1999). In other words, economic policy is not predetermined but is a reaction to changes in the economic system, and private investors base their expectations on the behaviour of economic policy makers. The expected change in the exchange rate regime will affect the variables (e.g. higher salaries, lower employment, higher interest rates) whose change increases the costs of maintaining the exchange rate regime. Once these costs have become too high, the economic policy makers may decide to devalue the currency and thus *ex post* confirm the expectations of market participants about the currency crisis (self-fulfilling expectations). Ozkak and Sutherland (1993) have shown that monetary authorities will be less willing to protect the exchange rate with higher interest rates in the event of a speculative attack if there is high unemployment, since this will only aggravate the unemployment problem. Furthermore, Obsfeld (1994) claims that a high level of public debt also increases the costs of exchange rate regime protection, thus increasing the probability of a speculative attack. Once the expectations regarding devaluation are incorporated in the nominal interest rate, the increased expenses of debt interest payment increase the costs of fixed exchange rate maintenance, which might trigger the decision to change the exchange rate regime. Moreover, the monetary authorities would probably not be too keen to defend the exchange rate by increasing interest rates, because of the concern that this might engender a banking crisis (due to maturity mismatching and credit risk in the period of recession) and the resulting fiscal costs of bailing out the banking sector (Obsfeld, 1996).

Thus a currency crisis, according to the exit clause model, develops in the situation where speculators perceive that, under the given conditions in the economic system, the economic policy makers have come to the point of applying the exit clause. From this derives the main implication of the second generation model: a currency crisis cannot be explained only as a consequence of change in economic fundamentals (Krueger, Osakwe, Page, 1998). Emphasis is placed on the idea that, while changes in economic fundamentals are a necessary condition for triggering a currency crisis, they are not the only condition. The key role in second generation models is played by changed expectations as the main cause of a currency crisis. It has to be stressed, however, that a self-fulfilling crisis does not imply that the attack is not related to economic fundamentals. It is true that the second generation models include an area of "strong" fundamentals, where an attack is not to be expected because the government will not abandon the fixed exchange rate under any circumstances,[8] making it illogical to expect devaluation and

8 See, for instance, the model in Sachs, Tornell and Velasco (1996).

attack a currency. However, these models also include an area of "weak" fundamentals, where the cost of maintaining a fixed exchange rate is so high that a speculative attack that will cause the abandonment of the fixed exchange rate is inevitable. Finally, there is also an area of medium vulnerability of fundamentals, which is usually associated with the possibility of multiple equilibria, where expectations have a direct impact on the creation of a certain equilibrium. One level of equilibrium is created in the situation where the fixed exchange rate would be maintained under favourable expectations but would not be sustainable if the expectations were to trigger an attack on the currency (the second equilibrium).[9] Under such circumstances, the elements causing a fall in confidence in the currency and enabling coordination of speculator expectations and actions [the "Sun spot" variable (Jeanne and Masson, 2000)] may result in a sudden attack on the currency (Flood and Marion, 1998). It is these coordination elements that are among the most important unresolved issues in the models of second generation currency crises, for a satisfactory explanation has still to be found for the causes of "a leap" from one equilibrium to another.[10] This leads us to one of the main characteristics of the second generation models as opposed to the first generation models – since the crisis depends largely on expectations, and there is no explanation for the loss of confidence and coordination of expectations, the time of attack and the onset of a currency crisis are impossible to determine.

### 2.3 Third Generation Models of Currency Crises

The first and second generation models focus on macroeconomic policy and consider that the abandonment of the exchange rate regime is caused by inconsistent economic policy or an inconsistent decision by the policy maker responsible for the assessment of the costs and benefits of maintaining the fixed exchange rate regime. Although certain authors question the need to distinguish a new set of models [e.g. Woo, Carleton and Rosario (2000), and Jeanne (1999)], certain aspects of currency crises in the countries of south-east Asia justify the establishment of a new set of models since they are related not only to economic policy but also to market imperfections or distortions in the financial system. New models, or third generation models of currency crisis, deal with a number of additional causes of currency crises.

The first group of models stresses problems in the banking system (a syndrome of overindebtedness abroad, moral hazard and asymmetric information in an environment of implicit guarantees from government[11] and international

9 For a formal, technical explanation of the area of economic fundamentals in the models of second generation currency crisis, see Obsfeld (1996), Flood and Marion (1998) and Jeanne (1999).

10 Partial explanations of coordination include the herd effect in global capital markets, expensive information and simultaneous decision making (Calvo and Mendoza, 2000), and also informational "cascades" (Banerjee, 1992), which are based on the sequential perception of third party actions irrespective of their own information. Probably one of the more important explanations concerns the existence of a large-scale investor (such as George Soros in the attack on the British pound in 1992); however, this explanation excludes multiple equilibria, for there is only the equilibrium with the attack on the currency, since a well financed, large-scale speculator will always use an opportunity for profit (Flood and Marion, 1998).

11 Due to government guarantees, fiscal problems will become evident *ex post*.

institutions, and inadequate supervision of the banking sector) as the most prominent factors in the Asian currency crises.[12] A banking system crisis will lead to a currency crisis by the first generation model mechanism, because government contingent liabilities (implicit guarantees) become commitments in the moment of crisis and result in an unsustainable fiscal deficit, with the central bank in the role of lender of the last resort. However, the measures taken are inconsistent with the maintenance of the fixed exchange rate.

The second group of models considers the main cause of a currency crisis to be the herd effect, which can be observed among bankers and portfolio managers. Certain distortions result in mass panic and the acceptance of actions undertaken by other investors who seek refuge in a foreign currency.[13]

The third group of models considers that a currency crisis is caused by the contagion effect. There are various explanations of crisis transmission from one country to another. One of the explanations is based on the negative impact of an identical exogenous shock experienced in a number of countries. A crisis can also be transferred by means of trade relationships when the depreciation of a currency in one country results in the reduced competitiveness of another country. Financial interdependence can contribute to the expansion of a crisis when the inability of a country to repay its external debt forces its foreign creditors to recall loans to other countries. Finally, a currency crisis in a particular country can contribute to the deteriorated perception of the condition of economic systems in other countries with similar system characteristics. The explanation of the contagion effect also contains elements of both the first and second generation models of currency crises (Pesenti and Tille, 2000). Identical exogenous shock, the influence of trade channels and the existence of joint creditors may be grouped as factors of crisis caused by economic fundamentals, while the role of capital market information is consistent with the self-fulfilling characteristics of a currency crisis.

## 2.4 Other Explanations of Currency Crises

A number of theoretical papers have focused on unconventional and non-economic factors in explaining currency crises in order to encompass the entire process of a currency crisis, to omit certain assumptions linked to "generational" models and to introduce some new assumptions for the purpose of a better representation of the actual events occurring in a particular country.

Among the more important interpretations of currency crises that fall outside the "generational" way of thinking is the Kindleberger-Minsky model, which describes three stages in a currency crisis: mania, panic and collapse. Mania is a period of upswing in the business cycle, when the market participants restructure their assets in favour of real and financial assets. Panic is characterized by the

12 For an explanation of the impact of the banking sector on the possibility of a currency crisis onset and vice versa, see Mishkin (1999) and G. L. Kaminsky and C. M. Reinhart (1996), and for a formal model, see Chang and Velasco (2001).

13 Various explanations of the herd effect may be found in Saxen (2001).

herd effect and competition in the transformation of real and financial assets into the most liquid form of assets. Collapse is the final stage of the process.

Saqib (2002) provides a model consisting of five different stages. A crisis starts with an exogenous shock (war, elections, discoveries, etc.) that has a strong impact on the economic system by changing the profit outlook in at least one sector of the economy. If the profit outlook is improved compared to the previous situation, investment and production increases at an accelerated pace. The existence of speculation is assumed, and this speculation encourages an increase in the price of the "object" of speculation (for instance, foreign currency, domestic or foreign bonds, land, buildings, etc.). This price increase attracts further investment and further income growth. The third stage is a process of overtrading and includes speculation (purchasing for the purpose of selling at a higher price) and excessive expectations (euphoric perception of the price of a particular object beyond its fundamental value). As production expansion continues, interest rates, prices and profits continue to increase. At a particular moment in the period of high profits, a number of investors with preferential information decide to sell the "object" they have bought. At the early stage, speculative entries continue and balance the exits. Prices stop increasing. This is a period in which speculators start seeing that a mass exit from the "community of speculators" might become probable, which eventually causes panic (due to a lack of liquidity that would enable each participant to sell at a profit). As speculators sell "objects", prices start falling, the number of bankruptcies increases, and the business situation worsens. Panic ends when the prices fall to such a low level that they are again attractive to speculators, when trading stops because the price of the "object" reaches its lower limit, or when the monetary authorities succeed in persuading the market that there is an adequate level of liquidity to stop the panic. The most frequent criticism of this model concerns its general nature, which does not provide a rigorous theoretical explanation for a currency crisis.

Other explanations of currency crises include structural and political factors.[14] Market euphoria (a structural factor), characterized by the mass entry of foreign capital, a high rate of economic growth, low unemployment etc., creates the "psychology of delusion" which obscures the negative trends in traditional factors or just neglects them. Political factors may also lead to questionable decisions. For example, election dates may influence the choice of time of devaluation: devaluation is an unpopular measure and is often postponed until after the elections since the appreciated currency generally means cheaper imported goods and therefore higher real wages (Stein and Streb, 1999). Furthermore, a "war of attrition" between political parties in a ruling coalition that are in conflict over an unsustainable fiscal deficit may result in the postponement of a political agreement on the reduction of the deficit, in the attempt to transfer the costs to the other side, leading to unwanted economic consequences and a currency crisis (Alesina and Drazen, 1991). Another political factor in a currency crisis concerns political instability and a tendency towards a deficit. Generally speaking, the more frequent

14 For a detailed discussion, see Saqib (2002).

the changes of parties in power, the greater the tendency towards a deficit (Alesina and Tabellini, 1990). Continued political instability leads to a persistent budget deficit, high external debt, an ineffective tax system and low growth rates (Saqib, 2002). These political factors have an indirect impact on expectations and on a speculative attack through economic fundamentals. This is why it is of crucial importance to analyse the political processes that lead to inconsistent policies and a currency crisis. Although these factors are often mentioned in the literature and have been supported by empirical evidence (for instance, Eichengreen, Rose and Wyplosz, 1996, or Bussière and Mulder, 1999), the theoretical model construction has not yet been brought to a satisfactory level.[15]

## 3 Empirical Models of Currency Crises

Numerous empirical papers[16] on currency crises focus on the description of stylized facts regarding the period preceding the currency crisis or on testing a specific theoretical model of a crisis. Theoretical knowledge also provides certain guidance regarding the choice of potential indicators of a currency crisis, which should reflect the economic fundamentals or variables that have an impact on market expectations.[17] That is why the establishment of weak or inconsistent economic fundamentals is a prerequisite for the design of an early warning system for a currency crisis.

More recent empirical research does not focus only on explaining the causes of a currency crisis. It does not differentiate between various indicators but considers a wide range of variables that can help in constructing a system for predicting a currency crisis. On the other hand, it can be claimed that there are situations when it is impossible to predict major distortions because of the reaction of economic policy to signalling indicators and the implementation of preventive measures (Berg and Pattillo, 1999a). In addition, the issue is raised of the universality of currency crises, that is, their determinants in all times and in all countries. Without universal characteristics of currency crises, it is impossible either to draw general conclusions based on past empirical research or to interpret findings in a rational way with regard to a single country (Berg and Pattillo, 1999b). However, because of the small number of currency crises in individual countries, empirical papers often lean toward a belief in similarities in the determinants of currency crises in different countries, derived from universal theoretical explanations of currency crises. In line with this belief, empirical research most often focuses on the panel analysis of crises in what are very different countries. We have lately

15 An initial introduction of political factors as key model variables explaining currency crises can be found in Drazen (1998).

16 A comprehensive overview of the empirical literature up to 1997 is to be found in G. L. Kaminsky, S. Lizondo and C. M. Reinhart (1997). For an overview of empirical studies in the period from 1997 to 2003, see Abiad (2003).

17 Although a currency crisis with self-fulfilling characteristics depends primarily on speculator expectations (and is therefore hard to predict), the worsening of economic fundamentals plays a role in shaping expectations in this case as well.

seen studies focusing on the construction of early warning systems applicable to a limited number of countries sharing similar characteristics but also analysing the issue from the perspective of a single country.

An early warning system encompasses a precise definition of a currency crisis, a selection of variables explaining its occurrence and a mechanism for predicting it, including a specific methodology enabling the prediction of a currency crisis with these variables (Berg, Borensztein, Milesi-Ferretti and Pattillo, 1999). Various empirical models apply various approaches to the process of forecasting a crisis and are related to practical problems which are the consequence of the currency crisis definition and the method of its prediction. The choice of variables depends on the theoretical insight, empirically confirmed facts regarding the movements of certain variables in the period preceding a crisis, and also on the availability of data.

### 3.1 Early Empirical Research

Before the currency crises of the 1990s, empirical studies were based on first generation models. Standard econometric methods were applied in these structural models, based on Krugman's model, in the attempt to test the factors in currency crises in a particular country in a specific period. Blanco and Garber (1986) used Krugman's model to predict the probability of a devaluation occurring at a particular moment in time as a consequence of the speculative attack on the Mexican peso. Used in the late 1980s, non-structured models, on the other hand, confirmed the importance of traditional factors in predicting a currency crisis (Kibritcioglu, Kose and Ugur, 1999). Edwards (1989) monitored the movements of various indicators before devaluation and compared them to changes in the same variables in a control group of countries that had succeeded in maintaining fixed exchange rate regimes over the same period of time.

Most of the currency crises that occurred in the 1990s could not be explained only by traditional factors, such as indicators of fiscal or monetary policy. This is what started the next wave of empirical research, which focused on a wider spectrum of various indicators, the implementation of panel-analyses and the search for generally valid characteristics of currency crises. Most of these analyses divided the available sample of variables into a tranquil period and a period of turbulence (pre-crisis period), but a variety of techniques were used, most frequently the non-parametric, signalling method and discrete choice models (probit/logit models).

### 3.2 Signalling Method

The non-parametric, signalling method is a method with two variables and relies on the comparison of movements of the chosen variables in a tranquil period with their dynamics immediately before the crisis. If the movement of a variable before the crisis differs from its usual movement, extreme values of the variable should be seen as warnings, signalling the possibility of a crisis. The signalling method

transforms the indicators of a currency crisis and the exogenous variables into binary variables based on certain threshold values. While the most frequently used threshold value for currency crisis indicators is a certain number of standard deviations from the average value of currency crisis indicators, percentile measures are used as indicators of exogenous variables. The threshold value is defined by "weighing" the percentage of inaccurately predicted currency crises with the percentage of accurately sent signals. In other words, the threshold is determined by minimizing the *noise-to-signal ratio*, defined as the ratio of inaccurate signals in a tranquil period divided by the ratio of accurate signals in the pre-crisis period.

The signalling method provides the best results when the behaviour of variables in the pre-crisis period is clearly different from their behaviour in a tranquil period (Vlaar, 2000). The origins of the signalling method may be found in the work of Eichengreen, Rose and Wyplosz (1995). Their work differs from the preceding empirical studies in its clear definition of a currency crisis. The authors define a currency crisis by means of the concept of speculative pressure, which is defined by a weighed average of the change in exchange rate, interest rates and international reserves. A currency crisis is defined as the moment when the index of speculative pressure (index of exchange market pressure) exceeds extreme values (Eichengreen et al., 1995). This method of detecting speculative attacks and currency crises is most often used in empirical papers based on other methods. The signalling method became popular through the work of G. L. Kaminsky and C. M. Reinhart (1996) and G. L. Kaminsky, S. Lizondo and C. M. Reinhart (1997), who, using a sample of twenty countries in the period from 1970 to 1995 and numerous variables (selected on the basis of theoretical considerations and available data), attempted to identify those factors that can be the best predictors of currency crises. The analysis based on a finite set of fifteen variables compares their values in the period of twenty-four months preceding the crisis with the values recorded in a tranquil period. Goldstein, G. L. Kaminsky and C. M. Reinhart (2000) developed a method of aggregating the "best" indicators into a composite indicator of a currency crisis.

Research into the determinants of currency crises was most often carried out on data from Asian countries and the countries of Latin America. Later, research expanded to countries in transition (e.g. Edison, 2000, or Brüggemann and Linne, 2002). Dahel (2000) tries to identify a system vulnerability to a currency crisis in Arab countries. A. Ahec-Šonje and Babić (2002) provide an analysis of currency crises in Croatia, using a standard signalling method where a currency crisis is defined by applying the index of exchange market pressure (as is the case in this paper) and including the explanatory variables with a monthly frequency and a composite indicator as a relevant signalling indicator of a currency crisis.

The most important deficiency of the signalling method is that the transformation of the exogenous variable into a binary one results in a loss of information on the relative importance of the values of the independent variable.[18] The problem of

18 Thus, for example, the value of a current account deficit of the balance of payments at 1% above the threshold has the same meaning in terms of signalling a currency crisis as does a deficit of 50% above the threshold.

information loss becomes even more prominent when the analysis uses a composite indicator of a currency crisis (Vlaar, 2000). The method also ignores the correlation between independent variables, which has a negative impact on the construction of a composite indicator (Eliasson and Kreuter, 2002). In addition, the signalling method does not allow the implementation of statistical tests. However, in spite of these deficiencies, the signalling method is an adequate one, provided that the analysis is focused primarily on the research of system vulnerability as it directly selects the variables best suited to anticipate any distortions in the foreign exchange market.

### 3.3 Discrete Choice Models

The largest group of empirical analyses use the technique of a discrete dependent variable (probit and logit) which associates a set of exogenous continuous variables with the probability of a currency crisis (Collins, 2003). While the dependent variable of a currency crisis remains a binary or multinomial variable, as in the signalling method, the independent variables are continuous. This approach provides the possibility of evaluating a formal model of relationships between various indicators and a discrete occurrence of a currency crisis. The econometric model evaluation offers a number of advantages over the signalling method. The model prediction is simply interpreted as the probability of a currency crisis occurrence. Also, since the method analyses the significance of all the variables simultaneously, the significance of an additional variable is easily checked. Finally, the model allows the use of various statistical tests to check the significance of a single indicator and of the regression results.

Eichengreen, Rose and Wyplosz (1996) were among the first to use probit regression; they applied it to data on twenty industrialized countries in the period from 1959 to 1993 in order to empirically identify the determinants of a currency crisis. One of the more important novelties introduced in their analysis is the contagion effect. Frankel and Rose (1996) applied probit regression to the yearly data for 105 developing countries in the period between 1971 and 1992. As opposed to most empirical analyses, these authors used the definition of a currency crisis that assumes that there are only successful speculative attacks.[19] Klein and Marion (1997) applied logit specification in their analysis of the collapse of exchange rate regimes in Latin America. Subsequent important papers applying the binomial probit model are: Goldfajn and Valdes (1997), Esquivel and Larrain (1998), Berg and Pattillo (1998a and 1998b), IMF (1998), Kruger, Osakwe and Page (1998), Caramazza, Aziz and Salgado (2000), Schardax (2002), Kumar, Moorthy and Perraudin (2002) and Collins (2003). Eliasson and Krauter (2001) and Bussiere and Fratzscher (2002) apply the multinomial logit. These empirical analyses differ in choice of indicators, sample of countries, definition of a currency crisis, prognostic time horizon and frequency of used data.

19 The definition of a currency crisis encompasses only currency devaluation (above 25%) without a decrease in international reserves or an increase in interest rates.

The probit/logit approach has been frequently criticized for a number of deficiencies. First, currency crises are rare (few ones can have the value of a dependent variable), so the model is not completely statistically reliable. Moreover, it is not easy to determine the marginal impact of a single variable on the probability of a currency crisis occurrence. Due to the non-linear nature of the probit/logit function, the contribution of a single variable is not constant and depends on the values of all the other variables, so it is not possible to directly define the relative signalling power of a single indicator (G. L. Kaminsky, S. Lizondo, C. M. Reinhart, 1997).

### 3.4 Other Empirical Methods

Numerous empirical studies have tried to resolve the problems inherent in the signalling approach and the discrete choice approach.[20] Sachs, Tornell and Velasco (1996) applied the regression approach to the countries hit by the "tequila effect" in 1994 in order to explain which countries were hit the hardest by the crisis in Mexico. The importance of the analysis lies in the fact that the currency crisis indicator is a continuous variable (defined as the weighted average of the decrease in international reserves and the currency depreciation).[21] Jeanne and Masson (1998), Fratzscher (1999) and Abiad (2003) use the Markov *switching* model in order to encompass the possibility of multiple equilibria. The contributions of these models, in comparison to the models using the index of speculative pressure, is that the parameters evaluated in the model and the data obtained reveal the state of the economy, so the model does not depend on an arbitrary decision on the time of onset of the currency crisis, based on the signal provided by the index of speculative pressure (i.e. on the choice of the threshold value and the time horizon of the crisis) (Abiad, 2003). Research by Nag and Mitre (1999) and Peltonen (2002) marked the start of predictions of currency crises with the help of *artificial neural network* (ANN) models. The advantage of ANN models is their flexible specification and their ability to encompass complex interactions between variables (Abiad, 2003). Of the other methods used to predict currency crises, the most numerous are the *value-at-risk* models, the auto-regression model of conditional hazard, the *VAR* model and *Fisher discriminant* analysis.[22]

Since the most prominent issue regarding empirical models, or the early warning system, is not related to the possibility of explaining and predicting past currency crises on the basis of *in-sample* variables but on the ability of the system to predict a future crisis, Berg and Pattillo (1999a, 1999b) started, after the currency crises in south-east Asia, a project to evaluate the three most popular empirical models: G. L. Kaminsky, S. Lizondo, C. M. Reinhart (1997), Frankel and Rose (1996) and Sachs, Tornell and Velasco (1996). The authors, using the same countries (in south-east Asia) and adapting the time horizon and the choice of

20 Up to 2003, the number of empirical analyses based on new methods equalled the number of studies based on the application of the signalling and probit/logit method (Abiad, 2003).

21 See also Vlaar (2000).

22 See Appendix I in Abid (2003).

variables, compared the currency crisis predicting power of these models out-of-sample. Their findings indicate that the models developed by Frankel and Rose (hereafter: the FR model) and Sachs, Tornell and Velasco (hereafter: the STV model) do not provide any better results than simple guessing would, while the model by G. L. Kaminsky, S. Lizondo and C. M. Reinhart (hereafter: the KLR model) offers somewhat better results. Since the STV model does not predict the moment of the crisis occurrence, they compared the predicting power of the currency crisis in the KLR model and in a comparable probit model (the same definition of a currency crisis, the same countries included, the same variables, etc.). Although both models are weak regarding their power to predict a crisis, it was demonstrated that the results obtained by probit analysis are generally superior. Berg, Borensztein, Masson, Milesi-Ferretti and Pattillo (1999) tried to improve the predicting power in the out-of-sample probit model presented by Berg and Pattillo (1999a). The model is limited to five variables (real exchange rate, increase in domestic credit, the ratio of M2 to net usable international reserves, deficit on the current account of the balance of payments, the ratio of short-term debt to international reserves). The same model was used by the IMF as a support in decision-making (Edison, 2000).

## 4 The Early Warning System of a Currency Crisis in Croatia

Only a small number of empirical research projects have focused on a single country, due to a shortage of data[23] which makes the early warning systems statistically not fully reliable and their results not robust enough. However, it has been shown (for example, Berg and Pattillo, 1999a) that a panel-analysis based on a sample including a number of countries yields weak results irrespective of the method applied, for there is a higher probability that the determinants of a currency crisis will stay more stable over time in a particular country than in a number of countries; this has also been the main criticism of panel-analyses (Kibritcioglu, Kose, and Ugur, 1999). Panel-analysis also creates problems with the choice and measurement of variables.[24] In addition to the problem of how to interpret results obtained through generalization from the perspective of a single country, it is also obviously necessary to channel research to a country level and then to combine the results obtained with the insights gained through panel-analysis.

Two different methods have been used in this paper in order to try and construct a robust early warning system of a currency crisis in Croatia. As the first

23 In addition to the empirical analysis using the signalling method by A. Ahec-Šonje and Babić (2002), another of not many empirical research projects completed from the perspective of a single country is presented in the paper by Kajanoja (2001), who tried to use a probit model to identify the determinants of a currency crisis in Finland.

24 Panel-analyses, for instance, always use international reserves in US dollars because of the ease of data comparison. The choice of this measure of international reserves does not guarantee an adequate calculation of the index of exchange market pressure. This is because the presentation of international reserves in US dollars (in the case when the dollar is not the prevailing currency in the international reserve structure) espouses the change in the index to the exchange rate movements of the currency that prevails in the international reserve currency structure.

step, the predicting power of a variable and the indicators of the system vulnerability to a currency crisis were identified with the signalling method. Then the indicators with the best *noise-to-signal ratio* were used in a binomial probit analysis with two variables (between the dependent variable of a currency crisis and each of the independent variables, i.e. each of the indicators of the currency crisis specified by the signalling method) in order to check the validity of the functional specification of the relationship between a specific variable and the dependent variable of a currency crisis characteristic of the signalling method. This method also checks whether other functional forms are possible. The evaluation of a probit model with several variables is an extension of the analysis of a probit model with two variables. First the two probit models with several variables that differ by functional form were evaluated. Significant variables with the expected sign were used in both models to evaluate a third probit model with several independent variables in various functional forms. Thus the third model, which is an alternative system to the signalling method for providing early warning of a currency crisis, is a combination of the two previously evaluated models. Each method of currency crisis prediction was evaluated in terms of their success in predicting a currency crisis in the sample.

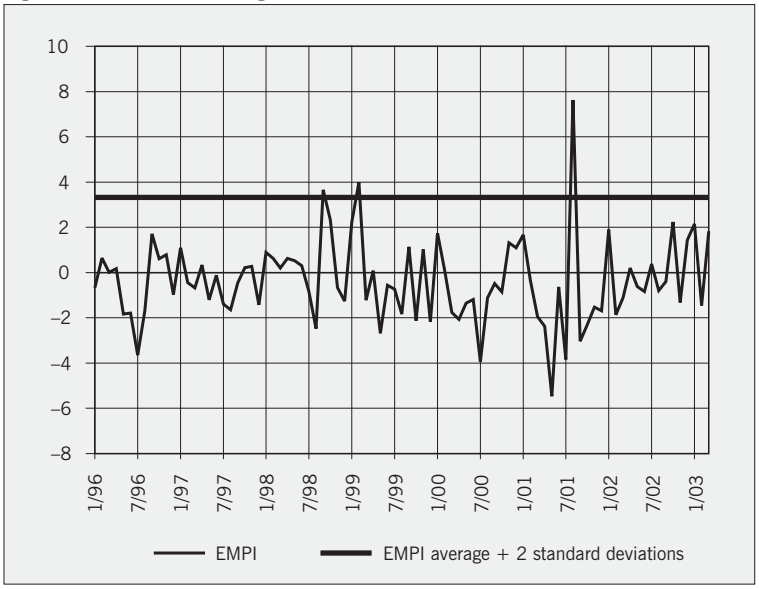
### 4.1 Definition of a Currency Crisis

The definition of a currency crisis is of paramount importance in the process of predicting a crisis. In theoretical literature, a currency crisis is mostly defined only in the case of fixed exchange rate regimes, usually as the official devaluation or abandonment of the fixed exchange rate regime. However, this definition is not flexible enough to serve in empirical research, since many currencies are not formally pegged to a specific currency and many countries use various forms of floating exchange rate regimes, as is the case in Croatia. This is why most empirical studies define a currency crisis as a large (either nominal or real) depreciation of the domestic currency. But monetary authorities can also fight a speculative attack by intervening in the foreign exchange market or by increasing interest rates. Unsuccessful speculative attacks are also included in the definition of a currency crisis since they point to the vulnerability of the system as seen in a fall in international reserves and a rise in interest rates.

The definition of a currency crisis used in this paper has been taken from the empirical research carried out by A. Ahec-Šonje and Babić (2002). According to them, a currency crisis is a situation characterized by a considerable nominal depreciation of the kuna against the euro (on a monthly level) and/or a fall in international reserves.[25] However, as opposed to Ahec-Šonje and Babić, whose definition of a currency crisis uses gross international reserves[26] expressed in US dollars, this

25 Interest rates are not included in the definition of a currency crisis because the Croatian National Bank's monetary policy does not rely heavily on changes in interest rates and thus the CNB reference interest rate (interest rate on CNB bills) does not play a relevant role in the financial system. So the CNB reference interest rate is not as important as the interest rates of central banks whose monetary policy is based on changes in the reference interest rate.

**Figure 1** Index of Exchange Market Pressure




Source: The author's calculation.

paper uses gross international reserves expressed in euros. The reason for this decision is the currency structure of Croatia's international reserves, where the share of euros amounts to about 75%. Thus the exchange market pressure index is given as the weighted average of the monthly rate of change in the kuna nominal exchange rate against the euro and the monthly rate of change in gross international reserves expressed in euros:[27]

$$ipdt_t = \%\Delta e_t - \alpha\%\Delta r_t \qquad (1)$$

where $e_t$ is the kuna exchange rate against the euro in period of time $t$, $r_t$ are international reserves expressed in euros, and $\alpha$ is the ratio of the standard deviation of the exchange rate change and the standard deviation of the change in international reserves. The exchange market pressure index is defined so that it is increased by kuna depreciation and a fall in international reserves.

The index signals a currency crisis (*ex post*) when its value exceeds the given threshold, which is equal to two standard deviations above the average index value [as specified in A. Ahec-Šonje and Babić (2002)]. Following this definition of the threshold value, a currency crisis is defined as a binary variable:

$$\begin{aligned} \textit{Currency crisis} &= 1 \textit{ if } ipdt_t > 2\sigma_{ipdt} + \mu_{ipdt} \\ &\quad \textit{(and eleven months before the onset of the crisis)} \\ &= 0 \textit{ in any other case} \end{aligned} \qquad (2)$$

26 Gross international reserves encompass those assets held by the CNB that can be used at any moment to bridge a mismatch in international payments as well as in the case of a potential currency crisis.

27 The weights have been chosen so that the two components have the same conditional variance (G. L. Kaminsky, S. Lizondo, C. M. Reinhart, 1997).

where $\sigma_{ipdt}$ is a standard deviation of the exchange market pressure index, and $\mu_{ipdt}$ is the index arithmetic mean. The index of exchange market pressure, thus defined, indicated two crisis episodes in Croatia: in September 1998 and August 2001 (Figure 1).[28]

### 4.2 Period (time horizon)

The results obtained in the model depend to a large extent on the period under review, the selection of pre-crisis period and the data frequency. Due to the problems encountered with the data preceding the stabilization program, this empirical analysis is based on monthly data collected in the period from January 1996 to March 2003. The data on variables published quarterly or yearly have been interpolated on a monthly level using the *cubic spline method*.[29] Because of the short time series, it was decided that the pre-crisis period lasts twelve months (before the moment of the onset of a currency crisis). This is the time interval when various signalling indicators of a currency crisis should signal the imminence of a currency crisis in the sample.

### 4.3 Independent Variables

The independent variables were chosen on the basis of observation of theoretical contributions to the understanding of currency crises, by applying a set of variables that have been proved useful by a large number of empirical research projects as well as the circumstances specific to the Croatian economic system. In order to enhance the possibility of identifying the crisis factors, the process of evaluating the model applies forty variables, grouped into four groups: variables related to the banking sector, to monetary policy, to foreign trade and to the real sector. The variables are defined in Appendix 1, while the economic justification of the choice of most of the variables to be applied to Croatia may be found in the paper by A. Ahec-Šonje and Babić (2002).[30]

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28 Although the index of exchange market pressure also exceeded the threshold value in February 1999 (the month marked as the beginning of a currency crisis in the paper by A. Ahec-Šonje and Babić (2002) due to the use of international reserves in US dollars in defining the index of exchange market pressure), it is obvious that the currency crisis had started in August 1998, when the CNB sold international reserves for the first time as a reaction to a sudden kuna depreciation. The reaction of the central bank was not effective enough since the decrease in international reserves, aimed at strengthening the kuna, was only stopped in May 1999.

29 The *cubic spline* method uses the third-degree polinomial to evaluate a series of spline functions between each of the pairs of given points, on condition that the resulting curve is continued and as "smooth" as possible. The conditions of this method allow for the "smoothness" of the curve (function, first and second derivation of the function are continuous in the entire interval, including the points of interpolation). For a detailed mathematical explanation, see McKinley and Levine (1998).

30 For a detailed overview of the characteristics of a pre-crisis period and of empirical facts regarding the behaviour of variables prior to the onset of a currency crisis in both developed and developing countries, see IMF (1998) and Aziz, Caramazza and Salgado (2000).

## 4.4 Methods of Prediction

As stated earlier, the analysis of currency crisis in Croatia will be based on two methods: the signalling method and the discrete choice model method, using a probit model. In addition to the results obtained by the use of each of the methods, a brief account of the technical details regarding each of the methods will also be provided.

### 4.4.1 Signalling Method

The signalling method assumes a difference in the behaviour of variables prior to the crisis and in the tranquil period. The method is based on the search for variables whose behaviour varies in the two periods. The variables that meet this criterion can be considered the signalling indicators of a currency crisis. In order to identify a change in the behaviour of a variable, it is necessary to define the threshold value to serve as the cut-off point between sustainable and unsustainable movement. The decision on the threshold value can result in a loss of accurate signals if the threshold is too high or in an excessively high number of inaccurate signals if the threshold is too low. A certain variable will signal a currency crisis if it exceeds the given threshold value in the pre-crisis period (12 months before the onset of the crisis). In addition, if a variable in the tranquil period does not exceed the given threshold (actual realization), this is also considered an accurate signal. If a variable exceeds the given threshold before the pre-crisis period, i.e. in the tranquil period, or if a variable does not exceed the threshold in the pre-crisis period (missed signal), the result is an inaccurate signal. These four situations allow the calculation of a noise-to-signal ratio (*hereafter:* NTS) for each variable as the ratio of inaccurate signals to accurate signals, as follows:

$$\omega_j = \frac{B/(B+D)}{A/(A+C)} \tag{3}$$

where $A$ is the number of months when variable $j$ sends an accurate signal of the upcoming crisis, $B$ is the number of months when the same variable sends an inaccurate signal, $C$ is the number of months of missed signals and $D$ is the number of months of actual realization, when a signal was not sent and a crisis did not occur. The optimum threshold value for each variable has been chosen so as to minimize the ratio of inaccurate signals to accurate signals, i.e. to minimize $\omega j$. Table 1 shows the ranking of variables based on an increasing NTS. Thus the top positioned variables have been singled out by the signalling method as the best indicators of a currency crisis. The results obtained by the signalling method are different from those obtained by A. Ahec-Šonje and Babić (2002) due to the use of interpolated data and a somewhat larger number of variables used as possible indicators of a currency crisis.

Generally speaking, the larger the number of indicators signalling a crisis, the higher the probability that a crisis will actually happen. Therefore it is reasonable to consider the vulnerability of a system to a currency crisis by the number of

**Table 1** Noise-to-Signal Ratio (NTS) per Variable ($\omega_i$)

| | Variable | NTS |
|---|---|---|
| **1.** | **CURRENT ACCOUNT BALANCE/GDP** | **0.10** |
| **2.** | **BALANCE OF PUBLIC FINANCES WITHOUT CAPITAL REVENUE/GDP** | **0.11** |
| **3.** | **INFLATION** | **0.15** |
| **4.** | **EXTERNAL DEBT (USD) (growth)** | **0.19** |
| **5.** | **BALANCE OF PUBLIC FINANCES WITH CAPITAL REVENUES/GDP** | **0.22** |
| **6.** | **REAL EXCHANGE RATE DEVIATION FROM TREND** | **0.26** |
| 7. | CREDIT (growth) | 0.30 |
| 8. | EXTERNAL DEBT/GDP (growth) | 0.30 |
| **9.** | **FOREIGN ASSETS/M4** | **0.32** |
| 10. | CREDITS/GDP (growth) | 0.33 |
| **11.** | **MULTIPLIER m2 (growth)** | **0.46** |
| **12.** | **FREELY AVAILABLE RESERVES OF BANKS/TOTAL BANK ASSETS** | **0.48** |
| 13. | MULTIPLIER m1 (growth) | 0.55 |
| 14. | BANK CLAIMS ON LOCAL AND CENTRAL GOVERNMENT /TOTAL BANK CLAIMS (growth) | 0.55 |
| 15. | MULTIPLIER M4 (growth) | 0.67 |
| 16. | CNB LOANS TO BANKS (growth) | 0.67 |
| 17. | FOREIGN TRADE (growth) | 0.82 |
| 18. | REAL KUNA/EURO EXCHANGE RATE | 1.02 |
| 19. | MONEY (M1a) (growth) | 1.02 |
| 20. | SHORT-TERM DEBT/GDP (growth) | 1.03 |
| 21. | TOTAL CAPITAL INFLOWS (growth) | 1.30 |
| 22. | IMPORT (USD) (growth) | 1.30 |
| 23. | MONEY (M1) (growth) | 1.30 |
| 24. | NET USABLE INTERNATIONAL RESERVES (EUR) (growth) | 1.30 |
| 25. | GROSS INTERNATIONAL RESERVES (EUR) (growth) | 1.30 |
| 26. | EXPORT (USD) (growth) | 1.71 |
| 27. | REAL INTEREST RATE (on the money market) | 1.90 |
| 28. | FOREIGN LIABILITIES OF MONETARY INSTITUTIONS (growth) | 1.90 |
| 29. | NOMINAL LENDING INTEREST RATE / DEPOSIT INTEREST RATE (with a currency clause) | 2.35 |
| 30. | REAL EFFECTIVE EXCHANGE RATE (retail prices) | 2.41 |
| 31. | EFFECTIVE EXCHANGE RATE DEVIATION FROM TREND | 2.41 |
| 32. | TOTAL CAPITAL OUTFLOWS (growth) | 2.41 |
| 33. | INDUSTRIAL PRODUCTION (growth) | 2.41 |
| 34. | RESERVE MONEY (M0) (growth) | 3.81 |
| 35. | NET USABLE INTERNATIONAL RESERVES/M4 (growth) | 3.81 |
| 36. | GDP (real) (growth) | 5.52 |
| 37. | M2/NET USABLE INTERNATIONAL RESERVES (growth) | 8.00 |
| 38. | BANK DEPOSITS (broad money; M4 – cash, growth) | 9.52 |
| 39. | NOMINAL LENDING INTEREST RATE/DEPOSIT INTEREST RATE | 16.00 |

Source: The author's calculation.

signals announcing it (Edison, 2000). One of the ways proposed by G. L. Kaminsky, S. Lizondo and C. M. Reinhart (1997) is to construct a weighted composite indicator, where the weights are the inverse values of the NTS of each variable. Variables with a low NTS would be given a higher weight than variables with a higher value. The composite indicator is defined by the following formula:

$$I_t = \sum S_t^j / \omega_j \tag{4}$$

where $S_t^j$ is equal to one if variable $j$ exceeds the threshold value in period $t$ and to zero in any other case. The choice of variables used in the construction of a composite indicator is based on the values of their NTSs. Goldstein, G. L. Kaminsky, C. M. Reinhart (2000) proposed the elimination of a variable whose NTS exceeds one since such a variable can be considered a poor indicator as its conditional probability of a crisis is lower than its unconditional probability of a crisis. Due to the large number of variables with an NTS not exceeding one, and also because of the low NTS value of the first few variables, which are therefore given a high weight in the calculation of a composite indicator, the NTS value of 0.50 (i.e. the border value that separates indicators to be used in the construction of a composite indicator) seems a reasonable one. Thus the values marked in bold in Table 1 will be used in the calculation of a composite indicator.

Although a composite indicator only serves for information purposes, in the sense of auguring a currency crisis, the value of the indicator does not directly provide any measure of the probability of a currency crisis being imminent and does not say anything about the dynamics of the currency crisis process. However, it allows, for certain composite index value intervals, the calculation of the corresponding conditional probability of a future crisis (Berg and Pattillo, 1998a). Conditional probabilities for a single interval are calculated using the following formula (Edison, 2000):

$$Vjer\,(K_{t,t+12} \mid I_i < I_t < I_j) = \\ = \frac{\sum \text{months where } I_i < I_t < I_j \text{ subject to a crisis onset in the next 12 months}}{\sum \text{months where } I_i < I_t < I_j} \tag{5}$$

where *Vjer* is a conditional probability of a currency crisis, $K_{t,t+12}$ is a currency crisis in interval $(t, t+12)$, $I$ is the weighted composite indicator, and $i$ and $j$ are the threshold and the ceiling of the weighted composite index interval. Thus $Vjer(K_{t,t+12} \mid I_i<I_t<I_j)$ shows the probability over time period $t$ that a crisis will occur in the course of the following 12 months, provided the value of the weighted composite indicator remains in the interval between $I_i$ and $I_j$. The distribution of conditional probabilities for a given composite indicator interval is shown in Table 2.

Defining the probability threshold allows the estimate of the power to predict a currency crisis in the sample, using the signalling method. The probability threshold of 0.50 (conditional probability of a crisis in the composite indicator value interval of 0.30 to 0.40) has been chosen as the cut-off probability,[31] since, once the value of the composite indicator exceeds 0.35, the probability of a currency crisis

31 In order to define the threshold value of the composite indicator, A. Ahec-Šonje and Babić (2002) use percentile measures. This technique, however, does not provide information about the probability of a crisis.

**Table 2** Conditional Probability per Given Composite Indicator Interval

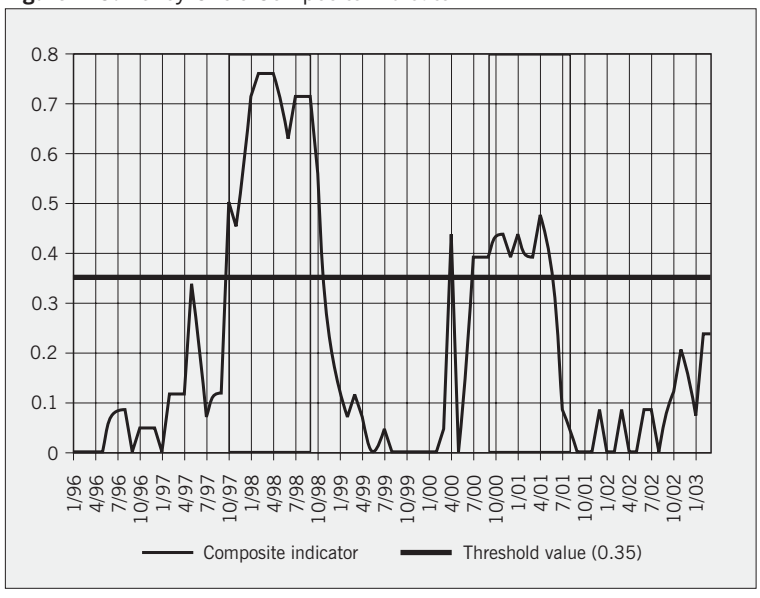
| Composite indicator values | Conditional probability |
|---|---|
| 0 – 0.10 | 0.02 |
| 0.10 – 0.20 | 0.09 |
| 0.20 – 0.30 | 0.14 |
| 0.30 – 0.40 | 0.50 |
| 0.40 – 0.50 | 0.78 |
| 0.50 – 0.60 | 1.00 |
| 0.60 – 0.70 | 1.00 |
| 0.70 – 0.80 | 1.00 |

Source: The author's calculation.

starts increasing and reaches very high values. This is why the probability threshold of 0.50 is the best compromise between the prediction of a crisis when it does not happen and the prediction of a crisis when it does happens. The movement of the composite indicator is shown in Figure 2, where pre-crisis time horizons of currency crises are also indicated together with the composite indicator threshold value.

Table 3 shows the goodness-of-fit measures of the composite indicator in predicting a currency crisis in the sample. It suggests that the composite indicator has a good ability to predict currency crises in this sample. The indicator accurately predicted a crisis in 87.5% of cases (months), and a tranquil period was accurately predicted in as many as 93.7% of cases. The probability of a crisis conditioned by the indicator signal (the ratio of the number of months when a crisis was accurately predicted to the sum of the number of months when a crisis was accurately predicted and of the number of months when a crisis was predicted but did not occur) equals a very high 0.840. Yet another way of evaluating the quality of a composite indicator is the *quadratic probability score (QPS)*. It measures the average difference between the event realization, $R_t$, and the evaluated event proba-

**Figure 2** Currency Crisis Composite Indicator




Source: The author's calculation.

**Table 3** Goodness-of-Fit of the Composite Indicator in Predicting a Currency Crisis in the Sample

| | | Actual | | Total number of months |
|---|---|---|---|---|
| | | Tranquil period | Crisis | |
| Predicted by the indicator | Tranquil period | 59 | 3 | 62 |
| | Crisis | 4 | 21 | 25 |
| | Total number of months | 63 | 24 | |
| Percentage of months with accurate crisis prediction[a] | | | | 87.5 |
| Percentage of months with accurate prediction of a tranquil period[b] | | | | 93.7 |
| Percentage of months with inaccurate crisis prediction[c] | | | | 6.3 |
| Percentage of well predicted observations[d] | | | | 92.0 |
| Probabaility of a crisis conditioned by a signal | | | | 0.840 |
| QPS measure | | | | 0.053 |

[a] Crisis is accurately predicted if the estimated probability exceeds the probability treshold and a crisis starts in the course of the next 12 months. [b] A tranquil period has been accurately predicted if the estimated probability does not exceed the probability treshold and a crisis does not start in the next 12 months. [c] An inaccurate signal is an observation in the situation when the estimated probability exceeeds the probability threshold, and a crisis does not start in the next 12 months. [d] A crisis not conditioned by a signal.
Source: The author's calculation.

bility, $P_t$. In this case, the event is a currency crisis, and the value of a currency crisis variable is equal to either one or zero. The *QPS* for *N* observations may be calculated using the following formula:

$$QPS = \frac{1}{N}\sum_{t=1}^{N} 2\left(P_t - R_t\right)^2 \qquad (6)$$

*QPS* lies in the interval [0.2] where a value equal to zero shows perfect prediction. As was the case with the previously mentioned measures, the *QPS* shows that the composite indicator has an adequate power for predicting a currency crisis.

### 4.4.2 Discrete Choice Model – Probit Model

Following the empirical confirmation of the relevance of the chosen set of variables as the currency crisis indicator when applying the signalling method, there arises the question of the validity of a functional relationship between the dichotomous variable of a currency crisis and the specific indicators used by the signalling method (*step* function). As stated earlier, due to the transformation of the indicator into a 0/1 variable on the basis of a given threshold, the signalling method provides good results provided there is a clear difference between the movement of variables in a tranquil period as opposed to a pre-crisis period. Therefore the validity of the form of functional connection between a single independent variable and the dependent variable of a currency crisis shall be examined by assessment of a probit model with two variables (with different specifications of the independent variable). The following step aims at avoiding the other drawbacks of the signalling method and at obtaining more robust results. Thus the variables selected by the signalling method as the best indicators of system vulnerability, i.e. of an upcoming currency crisis, will be entered, as exogenous variables, in the probit model with multiple variables, and the model will become an alternative to the signalling method regarding its ability to predict a currency crisis.

The probit model is a suitable instrument of analysis in the case of a binomial (or multinomial) dependent variable and a continuous independent variable. As opposed to a simple model of linear probability, the characteristics of the probit model are a non-linear relation between the independent variable and the probability that a dependent variable will become equal to one.[32] In addition, the probit model uses a probit function, which is actually a normal function of a cumulative distribution of the probability and allows the positioning of estimated values of the dependent variable within the interval [0.1]. The assumption of normal distribution refers to the distribution of random error, $\varepsilon_i$ in the linear probability model, which is the starting point for a transformation into a probit model (Maddala, 1992). The probability that $y_i = 1$ is equal to the probability that a random error will show the probability greater than the negative value of the deterministic segment of the linear probability model, i.e.:

$$Vjer(y_i = 1) = Vjer\left(\alpha_0 + \sum_{j=1}^{k} \alpha_j x_{ij} + \varepsilon_i \geq 0\right) = F\left(\alpha_0 + \sum_{j=1}^{k} \alpha_j x_{ij}\right) \qquad (7)$$

where $F$ is a cumulative distribution of the random error probability, which is here assumed to have a normal distribution pattern. Thus a final form of the probit model is obtained:

$$Vjer(y_i = 1) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\alpha_0 + \sum \alpha_j x_{ij}} e^{-t^2/2} dt \qquad (8)$$

where $t$ is a standardized normally distributed variable. Due to the absence of "realized probability" (since the dependent variable can have two values), it is not possible to evaluate the model using the OLS method,[33] and the ML (*maximum likelihood*) method is used instead, which evaluates the parameters by maximizing the probability (density) of observations of given values of the dependent variable (Santoso, 1996). In other words, under the assumption that the observations of the variable are independent, the parameters are evaluated in an iterative manner until the selection of parameters maximizes the probability function $L = \prod_{y_{i=1}} P_i \prod_{y_i=0} (1 - P_i)$ [34] (Verbeek, 2001).

The probit model has two advantages over the signalling method. First, it enables better aggregation of variables into a composite indicator of probability, which is not the case when the signalling method is used, while taking into

32 The estimated value of the model with binary dependent variable is actually the probability that a dependent variable $y_i$ will be equal to one, since the conditional expectation of a dependent variable in relation to the independent variable $x_i$, is equal to the conditional probability that the event will happen at a given value of $x_i$, *i.e.* $Vjer(y_i = 1 \mid x_i)$. Interpretation is possible since it can be shown that $E(y_i \mid x_i)$ is equal to the regression value (see Maddala, 1992, and Gujarati, 1995).

33 See in Gujarati (1995).

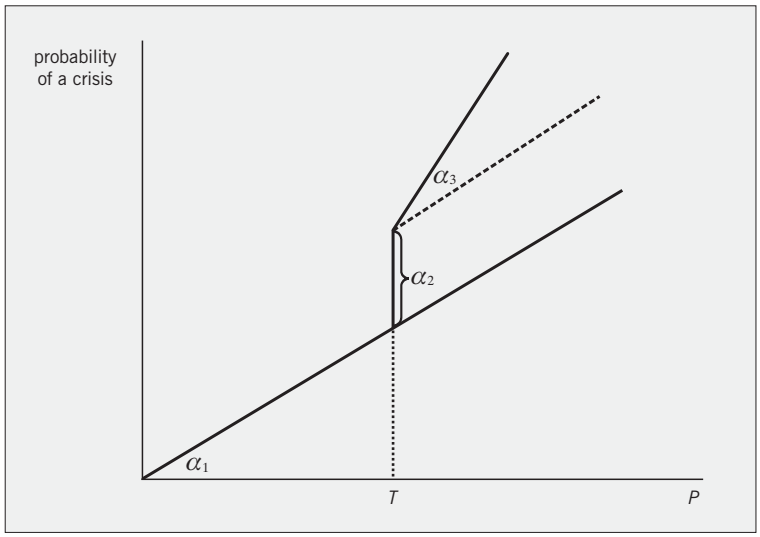
34 The form of a function showing the probability of a currency crisis is determined by the nature of the variable, whose realization is a binomial process.

account a correlation between variables (Berg et al., 1999). Second, the model allows statistical tests regarding the significance of each variable. In addition, the deficiency of a functional form in the signalling method (*step* function) has been avoided since the probit model allows the introduction of various functional forms between independent variables and the binomial dependent variable.

Prior to assessing the model with multiple variables, a probit model with two variables has been used to test the possibility of alternate functional forms between the dependent variable of a currency crisis and the independent variables, other than the specification 0/1. Figure 3 shows various options between a crisis probability (on the vertical axis) and the value of variable *P* (on the horizontal axis). The independent variable is measured in percentiles of its distribution over time in order to make comparison with the signalling method easier, since the threshold value is expressed as a percentile beyond which the variable signals a currency crisis (in Figure 3 marked with *T*). The signalling method, as presented in Figure 3, assumes the significance only of coefficient $\alpha_2$, which is equal to one, while coefficients $\alpha_1$ and $\alpha_3$ are, according to the signalling method, equal to zero (Berg and Pattillo, 1999a). In other words, it is assumed that the probability of a crisis is a *step* function of the indicator value (equal to zero when the indicator value is below the threshold, and equal to one when the indicator value is above the threshold). Alternative relations are, however, also possible. For instance, if $\alpha 1$ is different from zero and equal to $\alpha_3$, while $\alpha_2$ is equal to zero, there is a linear interdependence between the percentile value and the probability of a crisis. Figure 3 shows the next example of a possible correlation form – linear interdependence between the independent variable and the probability of a crisis up to the threshold value, beyond which the probability shows a steep increase to a higher level and starts to rise in an accelerated manner.

In order to verify the possibility of various specifications between various independent variables and the probability of a crisis (Figure 3), probit regressions

**Figure 3** Probability of a Crisis Against the Percentile Value of Independent Variable Distribution Over Time




Source: Berg and Pattillo (1999a).

were estimated with two variables between each exogenous variable and each endogenous variable of a currency crisis in the specification proposed by Berg and Pattillo (1999a) in line with the earlier discussion:

$$Vjer(crisis = 1) = f\left[\alpha_1 p(x) + \alpha_2 I + \alpha_3 I\left(p(x) - T\right)\right] \quad (9)$$

where a *crisis = 1* if the onset of a crisis is in the following 12 months, *p(x)* is the percentile of variable *x*, and $I = 1$ if the percentile exceeds the threshold $T$ (expressed as a percentile, and assigned values obtained by the signalling method analysis). Coefficients $\alpha_1$, $\alpha_2$ and $\alpha_3$ match those in Figure 3. Thus, provided that the signalling method offers a good specification of relationships, only $\alpha_2$ should be statistically significant and greater than zero. A significant coefficient $\alpha_1$ indicates a linear functional relation between a crisis variable and each indicator, while a statistically significant $\alpha_3$ stresses accelerated growth of the probability of a crisis once the percentile value of the indicator exceeds the threshold. Regression analysis follows the signalling method methodology regarding the currency crisis definition, its data, etc. Thus the values of a currency crisis variable are equal to one not only in the month of the crisis onset but also in the 11 months preceding the month of the crisis onset, which results in a number of advantages: it allows the use of data without a time lag and increases the number of ones in the sample from a statistical standpoint, which results in more reliable statistical indicators (Berg, Borensztein, Milesi-Ferretti and Pattillo, 1999).

The results of regressions with two variables are summed up in Table 4. It can be concluded that the "coefficient of the signalling method" $\alpha_2$ is not statistically significant in the case of certain variables (freely available bank reserves/total assets of banks, bank loans, deviation of the real exchange rate from the trend, foreign assets/M4, multiplier m2), while the percentile variable has proved relevant on a number of occasions to explain the variations in the probability of a crisis. This confirms the thesis that the signalling method assumption regarding the functional form of the connection between each of the independent variables and the dependent variable of a currency crisis is not valid in the case of some variables. This is why the method of identifying a crisis indicator with the threshold value is not effective, and the signalling method only indicates which variables can signal the system vulnerability. Due to the non-significance of the coefficient $\alpha_3$, the results obtained by applying a probit model with two variables indicate that there is no faster growth of the probability of a crisis once the value of the independent variable is beyond the threshold, indicating a linear correlation with the independent variable, while there is an increase in the probability of a crisis in the vicinity of the threshold value in the case of some other variables (current account balance/GDP, inflation, balance of public finance/GDP, external debt). Therefore such a specification of independent variables shall not be used in the assessment of a regression with multiple variables. It is also important to note that individual coefficients (mostly $\alpha_1$) have an unexpected sign for some variables (inflation, external debt, loans, multiplier m2). Table 4 shows in bold the functional forms that can be used in the interpretation of a currency crisis by one variable

**Table 4** Coefficients and T-Statistics of Specific Probit Models with Two Variables

| Variable | Coefficient (t-statistics in brackets) | | |
|---|---|---|---|
| | $\alpha_1$ | $\alpha_2$ | $\alpha_3$ |
| **Current account balance/GDP** | **–1,039** | **0,937** [a] | – |
| | **(–4,155)** | **(2,513)** | |
| **Balance of public finances/GDP** | **–0,933** | **1,118** [b] | 3,854 |
| | **(–3,796)** | **(1,394)** | (0,457) |
| **Inflation** | –2,534 | 2,136 | 3,983 |
| | (–4,778) | **(3,200)** | (–1,217) |
| **Freely available bank reserves/total bank assets** | **–3,149** | 0,517 | 2,497 |
| | **(–1,506)** | (1,030) | (0,929) |
| Bank loans (growth) | –1,696 | –1,479 | 33,853 |
| | (–4,260) | (–1,11) | (–2,431) |
| **External debt (growth)** | –2,520 | 2,002 | 7,016 |
| | (–4,954) | **(2,840)** | (1,422) |
| **Deviation of the real exchange rate from the trend** | **–1,761** | –0,159 [c] | –4,927 |
| | **(–5,298)** | (–0,279) | (–1,218) |
| **Foreign assets/M4** | **–0,981** | 0,358 | 0,969 |
| | **(–3,889)** | (0,664) | (0,268) |
| Multiplier m2 | –1,285 | 0,222 | 6,171 |
| | (–3,258) | (0,350) | (1,605) |

[a] The threshold value of the current account balance/GDP relates to the deficit on the current account of the balance of payments/GDP. [b] The threshold value of the balance of public finances/GDP relates to the deficit of the central government budget/GDP. [c] The threshold value of the deviation of the real exchange rate relates to the negative difference between the real exchange rate and its trend.

Source: The author's calculation.

only (they have the expected sign and are statistically significant to the level of 10%).

The statistical relevance of the functional correlation between a single independent variable and the dependent variable of the currency crisis, which differs from the one used by the signalling method, justifies the approach that uses a multiple variable probit model assessment as an alternative method in the prediction of a currency crisis. In the following section, we assess three probit models with multiple variables. In the first model, independent variables are expressed as indicators with their value equal to one if the variable value exceeds the threshold (specified by the signalling method) and equal to zero if the value does not exceed the threshold in a given month. In the second model, the independent variables are specified as percentiles of a certain independent variable distribution in the period under review, while the third model combines the independent variables in their different functional forms (indicator and percentile). Table 5 presents the results of the estimation of the first two models.

Testing the expected sign and the statistical significance of each coefficient in the equation used to assess the model enabled the elimination of insignificant variables with unexpected signs. Thus only three variables were left in the first model (balance of public finances/GDP, current account balance/GDP and deviation of the real exchange rate from the trend), and four in the second one (balance of public finances/GDP, inflation, external debt, deviation of the real

**Table 5** Estimated Probit Models with Multiple Variables (first step)

| Variable | 1st model (independent variable = 0/1) | | 2nd model (independent variable = percentile) | |
|---|---|---|---|---|
| | Coefficient | t-statistics | Coefficient | t-statistics |
| Balance of public finances/GDP | 1,699 [a] | 1,332 | –20,913 | –1,939 |
| Current account balance/GDP | 2,136 [b] | 1,572 | 1,490 | 0,466 |
| Inflation | 0,752 | 0,631 | 8,654 | 2,231 |
| External debt | 1,534 | 1,258 | 15,641 | 1,977 |
| Foreign assets/M4 | 1,000 | 1,110 | 3,703 | 0,903 |
| Multiplier m2 | 1,899 | 1,622 | –0,031 | –0,013 |
| Real exchange rate deviation | 2,627 [c] | 2,143 | 14,125 | 1,790 |
| Freely available bank reserves/total bank assets | –0,075 | –0,097 | –10,680 | –2,090 |
| Placements | –1,518 | –1,176 | –7,277 | –1,702 |
| constant | –3,689 | –3,131 | –7,564 | –1,248 |
| Log-likelihood | –15,553 | | –9,695 | |
| McFadden $R^2$ | 0,696 | | 0,811 | |

[a] The threshold value of the current account balance/GDP relates to the deficit on the current account of the balance of payments/GDP. [b] The threshold value of the balance of public finances/GDP relates to the deficit of the central government budget/GDP. [c] The threshold value of the deviation of the real exchange rate relates to the negative difference between the real exchange rate and its trend.

Source: The author's calculation.

exchange rate from the trend), which have the expected sign in the model and are both individually and jointly significant for the model. These variables were then used in different significant forms in the assessment of the third probit model with multiple variables (Table 6) since it was not possible to assess the third model with all the variables and their specifications included (as was the case in the first and the second models) due to the excessive number of independent variables (eighteen).[35]

The final probit model with multiple variables was estimated as before, using the criteria of the expected sign preceding an independent variable and the statistical significance in the third model (Table 7). This was the basis on which the results were subsequently interpreted and the *goodness-of-fit* of the model was assessed. Only one variable (current account balance/GDP) was included in the multiple variable probit model in the "signal" form, as an indicator (current account balance/GDP), while the other significant variables were expressed as percentiles (balance of public finances/GDP, inflation, external debt and the deviation of the real exchange rate from the trend). The statistical characteristics of the model are favourable. All the variables are significant to the level of 5%. The *LR measure*[36] shows the general statistical significance of the model (zero hypothesis of no significance of all the coefficients in the model was rejected with a significance of 1%), and *McFadden* $R^2$ [37] indicates relatively good goodness-of-fit in the model.

35 The introduction of a large number of independent variables in the model increases the probability of linear dependence between individual independent variables. The consequence is the impossibility of inverting the matrix of values of independent variables in the iterative manner to evaluate a probit model parameters, since this would be the case of a near-singular matrix (a matrix without a full rank).

**Table 6** Estimated Probit Models with Multiple Variables (second step)

| Variable | 1st model (independent variable = 0/1) | | 2nd model (independent variable = percentile) | | 3rd model (independent variable = combination) | |
|---|---|---|---|---|---|---|
| | Coefficient | t-statistics | Coefficient | t-statistics | Coefficient | t-statistics |
| Balance of public finances/GDP (percentile) | | | –8.369 | –3.185 | –18.260 | –2.676 |
| Balance of public finances/GDP (indicator) | 2.854[a] | 4.926 | | | –2.586[a] | –1.489 |
| Balance of current account of the balance of payments/GDP (indicator) | 2.567[b] | 4.627 | | | 4.246[b] | 2.554 |
| Inflation (percentile) | | | 5.417 | 3.769 | 7.536 | 2.517 |
| External debt (percentile) | | | 9.462 | 3.248 | 12.932 | 2.374 |
| Real exchange rate deviation (percentile) | | | –4.104 | –3.052 | –5.992 | –1.967 |
| Real exchange rate deviation (indicator) | 1.337[c] | 2.567 | | | –0.189[c] | –0.127 |
| constant | –2.294 | –5.279 | –3.080 | –2.241 | –1.557 | –0.690 |
| Log-likelihood | –19.489 | –15.991 | | –9.287 | | |
| McFadden $R^2$ | 0.620 | 0.688 | | 0.819 | | |

[a] The threshold value of the current account balance/GDP relates to the deficit on the current account of the balance of payments/GDP. [b] The threshold value of the balance of public finances/GDP relates to the deficit of the central government budget/GDP. [c] The threshold value of the deviation of the real exchange rate relates to the negative difference between the real exchange rate and its trend.

Source: The author's calculation.

In order to be able to use the estimated probit model as an early warning system of a currency crisis, it is necessary to estimate the power of the model in predicting a crisis in the sample. The standard method compares the estimated probabilities of a crisis with actual occurrences. To this end, a probability threshold was set to serve as a criterion for the decision whether a model signals a crisis or not. The probability threshold, as the value separating the pre-crisis period from the tranquil period, was set in the same manner as with the signalling method, and for the same reasons, at 0.50. The measures of goodness-of-fit (Table 8) indicate that the model has considerable potential to predict a currency crisis in the sample. The model accurately predicted a crisis in as many as 95.8% of cases (months) and accurately predicted a tranquil period in 96.8% of cases, with the conditional probability of 0.920. The model was wrong in predicting a crisis in only 3.2% of cases. Considerable potential to predict a currency crisis is also indicated by the *QPS measure*, the value of which is close to zero.

36 *LR measure* is equal to the multiple of (-1) and the difference between the logarithm of the maximum of the probability function with a restriction on parameters (in this case the restriction requires all the parameters to be equal to zero) and an "average" logarithm of the function probability maximum without a restriction. Therefore a larger *LR measure* relates to a higher statistical significance of the model. *LR measure* is analogue to the *F measure* in the models estimated by OLS.

37 *McFadden* $R^2$ is a measure of the goodness-of-fit of a model that is obtained when the ratio of the log of the function maximum with a restriction on parameters (all parameters equal zero) and the log of the probability function maximum without the restriction regarding the parameters are deducted from one; it corresponds to $R^2$ as a measure of goodness-of-fit of models estimated by OLS.

**Table 7** Multiple Variable Probit Model and Statistical Characteristics of the Model

| | | | | |
|---|---|---|---|---|
| Dependent variable: CRISIS | | | | |
| Assessment method: ML - binary probit | | | | |
| Sample: 1996:01 2003:03 | | | | |
| Number of observations: 87 | | | | |
| Convergence after 7 iterations | | | | |
| **Variable** | **Coefficient** | **Standard error** | **t-statistics** | **p-value** |
| Current account balance/GDP (indicator) | 3.086[a] | 1.148 | 2.687 | 0.007 |
| Balance of public finances/GDP (percentile) | –11.042 | 3.484 | –3.169 | 0.001 |
| Inflation (percentile) | 4.547 | 1.623 | 2.801 | 0.005 |
| External debt, growth (percentile) | 8.583 | 3.498 | 2.453 | 0.014 |
| Deviation of the real exchange rate (percentile) | –4.405 | 1.572 | –2.801 | 0.005 |
| constant | –1.653 | 1.607 | –1.029 | 0.304 |
| Standard error of a regression | 0.185 | | | |
| Log likelihood | –10.541 | | | |
| Log likelihood with a limitation | –51.243 | | | |
| LR measure (3 ss) | 81.403 | | | |
| Probability (LR measure) | 0.000 | | | |
| Average log likelihood | –0.121 | | | |
| McFadden $R^2$ | 0.794 | | | |
| Number of observations = 0 | 63 | | | |
| Number of observations = 1 | 24 | | | |
| Total number of observations | 87 | | | |

[a] The threshold value of the current account balance/GDP relates to the deficit on the current account of the balance of payments/GDP.

Source: The author's calculations.

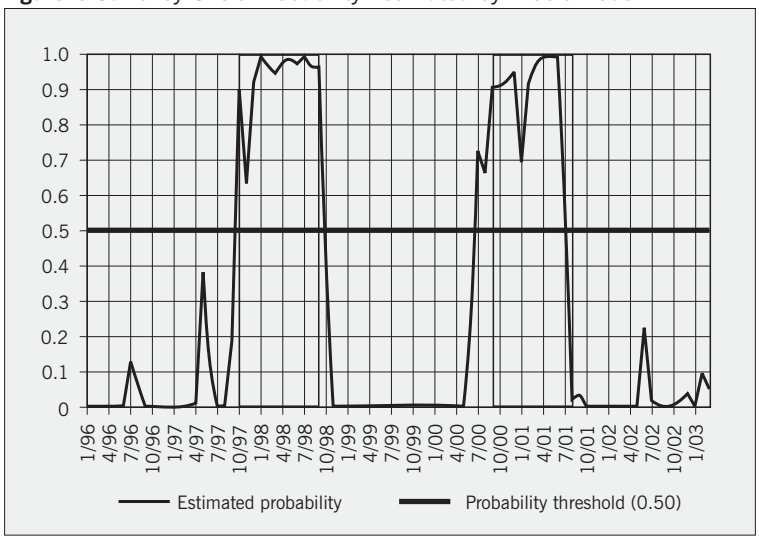
**Table 8** Goodness-of-Fit of the Multiple Variable Probit Model

| | | Actual | | Total number of months |
|---|---|---|---|---|
| | | Tranquil period | Crisis | |
| Predicted by the model | Tranquil period | 61 | 1 | 62 |
| | Crisis | 2 | 23 | 25 |
| | Total number of months | 63 | 24 | |
| Percentage of months with accurate crisis prediction[a] | | | | 95.8 |
| Percentage of months with accurate prediction of a tranquil period[b] | | | | 96.8 |
| Percentage of months with inaccurate crisis prediction[c] | | | | 3.2 |
| Percentage of well predicted observations[d] | | | | 96.6 |
| Probabaility of a crisis conditioned by a signal | | | | 0.920 |
| QPS measure | | | | 0.024 |

[a] Crisis is accurately predicted if the estimated probability exceeds the probability treshold and a crisis starts in the course of the next 12 months. [b] A tranquil period has been accurately predicted if the estimated probability does not exceed the probability treshold and a crisis does not start in the next 12 months. [c] An inaccurate signal is an observation in the situation when the estimated probability exceeeds the probability threshold, and a crisis does not start in the next 12 months. [d] A crisis not conditioned by a signal.

Source: The author's calculation.

**Figure 4** Currency Crisis Probability Estimated by Probit Model




Source: The author's calculation.

Very good model goodness-of-fit measures is seen in Figure 4, which shows the estimated probability of a currency crisis using the probit model with an indication of the probability threshold (beyond which the model signals a crisis) and the period immediately before a crisis when the model should accurately signal a currency crisis.

Comparison of the results obtained by the signalling method and the probit model regarding their ability to predict a crisis leads to the conclusion that the probit model provides somewhat better results, although they cannot be compared directly since the range of variables is different.

The probit model also allows the ranking of indicators according to the marginal contribution of each independent variable to the probability of a currency crisis. However, as the model is non-linear, the marginal influence of an independent variable is not a constant but depends on each of the independent variable values and on the values of all the other independent variables.[38] Thus the estimated coefficients cannot be interpreted as marginal contributions of independent variable to a dependent variable probability.

The marginal influence of an independent variable may be estimated if certain values of independent variables are assumed. Empirical research almost always estimates the marginal impact of independent variables with an assumed average of independent variables, and this has been done in this case as well. The average value of independent variables in percentiles is actually a median of the original time series of these variables. In the case of binary independent variables (current account balance/GDP), the literature recommends the assessment of the change in the probability of a currency crisis when the binary independent variable

38 The marginal influence of the independent variable $X_{ij}$ on the probability $P_i$ in a probit model is given as $\frac{\partial P_i}{\partial x_{ij}} = \alpha_i f\left(\alpha_0 + \sum \alpha_i x_{ij}\right)$, where $f(.)$ is the function of the density of a standard normal distribution (Verbeek, 2001).

changes its value from zero to one, with the assumption that all other independent variables remain unchanged, at the average value (Verbeek, 2001).

Table 9 shows the quantitative effects of an independent variable change on the estimated probability of a currency crisis in a number of different scenarios. Value deviations have been calculated for each independent variable from the series median equal to 1%, i.e. one percentage point, as well as deviations from the series median equal to the amount required to bring the variable value to the threshold value (used in the signalling method as a threshold above or below which the indicator signals a currency crisis). Deviations from the median of independent variables (deviation of the real exchange rate from the trend, external debt, inflation and the balance of public finances/GDP) have been calculated on the basis of the original values for each variable and then transformed into a percentile and used in the probit model. The first row in Table 9 shows the expected probability of a crisis when the values of independent variables are deviations of the real exchange rate from the trend, external debt, inflation and the balance of public finances/GDP equal to the average (median of original series) over the whole period under review, while the value of the share of the current account balance in the GDP variable is equal to zero. In this case, the risk of a currency crisis onset in Croatia in the following 12-month period is 0.25%. The expected probability of 0.25% is considered to be the benchmark value used to assess the contribution of each independent variable, depending on their assumed change from the average, or, depending on their leap from one to zero. The other rows in Table 9 provide an insight into the importance of the influence of specific variables on the onset of a currency crisis in Croatia. *Ceteris paribus*, a fall in the share of the current account balance in GDP to the level of the threshold value signalling a crisis (defined by the signalling method to be –8.8% GDP) will increase the probability of a currency crisis by 60.6 percentage points. Furthermore, if the values of

**Table 9** Impact of a Single Independent Variable on Estimated Probability of a Currency Crisis

| Scenario | Expected probability | Probability change |
|---|---|---|
| 1. Value of the deviation of the real exchange rate, inflation, external debt, share of the balance of public finances/GDP are equal to the median of the original variable series, current account balance/GDP is equal to zero. | 0.247% | |
| 2. All the variable values are equal to the values under 1 above, except the median deviation | | |
| A) current account balance/GDP = 1 | 60.826% | 60.579 p.b. |
| B) balance of public finances/GDP (-1 p. p. from the median) | 2.493% | 2.246 p.b. |
| C) balance of public finances/GDP (level equal to threshold value = –3.4 p. p. from the median) | 85.388% | 85.141 p.b. |
| D) inflation (+1 p. p. from the median) | 1.569% | 1.322 p.b. |
| E) inflation (level equal to threshold value = +1.3 p. p. from the median) | 2.859% | 2.612 p.b. |
| F) external debt (+1 p. p. from the median) | 0.404% | 0.157 p.b. |
| G) external debt (growth rate equal to threshold value = +23 p. p. from the median) | 40.647% | 40.400 p.b. |
| H) deviation of the real exchange rate (–1% from the median) | 0.283% | 0.036 p.b. |
| I) deviations of the real exchange rate (level equal to threshold value = –183% from the median) | 4.362% | 4.115 p.b. |

Source: The author's calculation.

all the other variables remain unchanged, a fall in the share of the balance of public finances by 1 percentage point below the median will not affect the probability of the onset of a crisis in any major way. But if the ratio of the balance of public finances and GDP falls to the level of the threshold value (defined by the signalling method to be –6.7% GDP), the probability of a crisis increases by 85 percentage points. A change in inflation will make a very modest contribution to the change in the expected probability of a currency crisis. When inflation exceeds the threshold value, the probability of a crisis increases by 2.6 percentage points, provided the values of the other variables are at the median level, or zero. An increase of 1 percentage point up from the median value in the rate of growth of external debt does not have a considerable impact on the probability of a crisis; however, an increase in the rate of growth to the level of the threshold value will increase the probability of a crisis by 40 percentage points. Finally, rows H) and I) show the effects of change in the deviation of the real exchange rate from the median of the percentile series of deviations of the real exchange rate from the trend on the probability of the onset of a currency crisis. A negative deviation of the real exchange rate from the trend from a value equal to the median of the time series to the level of the threshold value results in an increase in the probability of the onset of a currency crisis of 4.1 percentage points.

## 5 Interpretation of Findings

Empirical analysis (and primarily the findings of the composite indicator analysis) as well as the overview of the movement of variables that were selected as the most reliable signalling indicators of a currency crisis in Appendix 2 indicate that two currency crises in Croatia were not identical in nature and that different determinants have a different success rate in signalling a currency crisis. The first crisis in 1998 was, according to empirical findings, connected with a high rate of growth of domestic credit, a fall in freely available bank reserves, a fall in the share of foreign assets of the Croatian National Bank in M4, a growth in external debt and a large share of the deficit on the current account in GDP. The second crisis, that is, the second pre-crisis period in 2001, was characterized by a high level of the multiplier m2, a high level of budget deficit in GDP and the growth of freely available reserves. Inflation growth and appreciation of the real exchange rate marked both crises. These results are fully in line with the circumstances in the Croatian economy immediately preceding the onset of these crises.

Indicators of the first currency crisis may be found in the literature on third generation currency crises, which describes the correlation between banking problems and a currency crisis. According to the index of exchange market pressure, the first currency crisis started when the banking crisis reached its climax with all the characteristics described in the literature on third generation currency crisis models: a high rate of economic growth followed by a recession, credit expansion (which was partially used to increase imports and the deficit on the current account following the liberalization of foreign trade), external financial

market liberalization, accompanied by foreign capital inflow (deposit repatriation), liberalization of the domestic financial market without an adequate supervision mechanism, moral hazard in the banking system, an increase in external debt, appreciation of the exchange rate, a decrease in freely available bank reserves following a withdrawal of deposits under the impact of growing mistrust in the banking system, etc. In addition, maturing foreign loans taken by banks and capital restrictions imposed by CNB in the first half of 1998 helped reveal the inability of some of the banks to maintain their international liquidity. When these banks' problems were made public, a run on the banks followed and both kuna and foreign currency deposits were withdrawn from these banks. Since most banks were in the situation of mutual exposure, the difficulties experienced by one bank soon spread to other banks. The exchange rate depreciated steeply because of a high demand for foreign currency, particularly in the form of panic-driven purchases of foreign currency by banks in order to meet their liabilities at any price.

The background to the second crisis in 2001 was considerably different. The factors and circumstances present in the system indicate that the 2001 currency crisis can be explained by exit clause models. The pre-crisis period was marked by a pronounced appreciation of the nominal exchange rate. The sources of the appreciatory pressures can probably be located in the high budget deficit financed in the foreign financial market, privatisation revenues and a successful tourism season. By intervening in the foreign exchange market (purchasing foreign exchange), CNB tried to alleviate the appreciation of the kuna against the euro. However, the exchange rate did not stabilize and there was a strong and, from the seasonal point of view, unusual kuna depreciation against the euro in August. Because of the very low price of foreign exchange, banks and companies (financial liberalization in the first half of 2001 enabled legal entities to hold foreign currency on their accounts) probably decided to speculate on the exchange rate change with possible self-fulfilling features.[39] At the moment of crisis, the exchange rate depreciated by 5.91% (August 2001) on a monthly level and thus confirmed the expectations of speculators. However, CNB started selling international reserves and staged a forceful reaction (reducing the permitted exposure to currency risk of the overall bank foreign exchange position from 25% to 20% of the capital base, increasing interest rates on Lombard loans, since banks were using Lombard loans to cover the lack of kuna while they were purchasing foreign exchange for speculative purposes, reducing the remuneration rate on the specific kuna portion of the reserve requirements and consolidating the reserve requirements in the specific currency), and these CNB measures reduced the demand for foreign currency and prevented a continued kuna depreciation.

39 Speculative sources are evident from the huge increase in the company kuna deposits in July 2001.

## 6 Conclusions

After an overview of the theoretical and empirical literature, the empirical analysis of a currency crisis by means of standard research methods has shown that currency crises in Croatia can be predicted by their characteristics. After considering numerous variables in the period from January 1996 and March 2003, the signalling method was used to identify the indicators of vulnerability of the economic system to a currency crisis: the share of the balance of public finances in GDP, the share of the current account balance in GDP, inflation, the share of freely available bank reserves in the total bank assets, external debt, multiplier m2, deviation of real exchange rate from the trend, the share of foreign assets in M4, and growth in domestic credit. The statistically more rigorous probit model method was used to select from the vulnerability indicators the five variables of different specifications that can best empirically illustrate the situation preceding the onset of the two currency crises in Croatia. Thus the appreciation of the real exchange rate below the trend, a fall in the share of the balance of public finances in GDP, a fall in the share of current account balance in GDP, a rise in inflation and a rise in external debt increase the probability of a speculative attack on the kuna. The signalling method and the probit model both showed a considerable power to predict a currency crisis in the sample; this indicates that the construction of an early warning system, to be used as a support measure of economic policy, should include the results obtained by both methods.

An early warning system provides indications regarding the cause of difficulties in the Croatian economic system from the perspective of distortions in the foreign exchange market. However, if the goal of the analysis is to implement economic policy measures in order to avoid a crisis, then a more detailed exploration of the sources of difficulties should be undertaken. In addition, factors of a political and institutional nature, not included in the early warning system, may play an important role in the process of explaining distortions in the foreign exchange market. Moreover, notice should be taken of "technical" problems connected with the signalling method and the probit model (the definition of a currency crisis, selection of the time horizon of the pre-crisis period, dependence of the results on the choice of a threshold value as the marginal value distinguishing the "crisis-like" behaviour of the variable from the "non-crisis-like", frequency of data on a monthly level regarding certain variables obtained by interpolation, and the small number of crisis occurrences with different characteristics, which affects the statistical reliability of the probit model). Empirical studies have shown that the temporal stability of the early warning system is questionable, not only regarding the model parameters but also regarding the choice of variables. This has proved important in this research project since the analysis indicated two crises, i.e. the characteristics of a pre-crisis period were located in two cases only. In other words, since the early warning system (either based on the signalling method or on the probit model) assumes the possibility of predicting a future currency crisis based on *ex post* empirically selected indicators, the behaviour of which marked the period immediately preceding the two currency crises in

Croatia, it is questionable whether the system will prove useful in predicting the next currency crisis. This is related to one of the greatest problems encountered in almost all empirical research projects: while the possibility of predicting a currency crisis in the sample by using the model is considerable, the same conclusions need not necessarily apply to the predicting power of a crisis outside the sample. Hence an early warning system cannot be a substitute for reason and common sense on the part of the economic policy makers. However, the system should provide, as a complementary support, an impartial and objective measure of risk of a possible future currency crisis provided all the limitations and assumptions are taken into account.

## Appendix 1
## Description of Time Series of Variables

1) Current account balance/GDP – the share of the twelve-month moving sum of the current account balance on the balance of payments at a monthly level in the twelve-month nominal GDP moving sum (interpolated from the three-month to one-month level by the method of cubic splines); the current account balance of the balance of payments and GDP expressed in US dollars.

2) Balance of public finances/GDP – the share of the twelve-month moving sum of the balance of public finances (total surplus/deficit) at a monthly level in the twelve-month nominal GDP moving sum (interpolated from the three-month to one-month level by the cubic spline method); the balance of public finances and GDP expressed in kunas; two variants of the variable balance of public finances/GDP are used: in the first variant, public finance revenues include capital revenues, while capital revenues are excluded in the second one.

3) Inflation – the year-on-year rate of change in the retail price index.

4) External debt – the year-on-year rate of change in external debt expressed in US dollars; stock of external debt at the end of the period (month) from January 1996 to December 1998 is the stock of external debt interpolated from a year-on-year to a monthly level, while in the period from January 1999 to December 1999, the stock of external debt was interpolated from a three-month to a monthly level.

5) Deviation of the real exchange rate from the trend – deviation of the real exchange rate of the kuna against the euro [derived as a quotient of the multiple of the nominal exchange rate and the core retail price index (base year = 1996) and the core harmonized index of consumer prices (base year = 1996)] using a linear trend.

6) Loans – the year-on-year rate of change in bank loans (in kuna, in kuna with a currency clause, foreign exchange loans) granted to other domestic sectors (households, corporates and government) expressed in kunas.

7) External debt/GDP – the share of external debt at the end of a month in the twelve-month GDP moving sum (interpolated from a three-month to a monthly level using the cubic spline method); external debt and GDP expressed in US dollars.

8) Loans/GDP – the share of the balance of loans granted by banks to other sectors in nominal GDP (interpolated from a three-month to a monthly level using the cubic spline method); loans and GDP expressed in kunas.

9) Multiplier m2 – the year-on-year rate of change of the multiplier m2 as a quotient of M2 and M0; M2 includes M1 (currency outside banks, deposits by other banking institutions and other domestic sectors with the CNB and demand deposits with banks) and kuna savings deposits by other domestic sectors, other banking institutions and other financial institutions with banks; M2 expressed in kunas.

10) Freely available reserves of banks/total assets of banks – the share of freely available reserves of banks (total kuna reserves minus the required

reserves) in the total assets of banks; freely available bank reserves and total assets of banks expressed in kunas.

11) Multiplier m1 – the year-on-year rate of change in the quotient of M1 (money supply) and M0 (reserve money); M1 and M0 expressed in kunas.

12) Bank claims on local and central government/total bank claims – the year-on-year rate of growth of the share of bank claims on local and central government in the total bank claims; bank claims and total bank assets expressed in kunas.

13) Multiplier m4 – the year-on-year rate of change in the ratio of M4 (total liquid assets that include money supply, M1, savings and time deposits, foreign currency deposits and bonds and money market instruments) and M0; M4 and M0 expressed in kunas.

14) Foreign assets/M4 – the share of foreign assets of the CNB in M4; foreign assets and M4 expressed in kunas.

15) Loans by CNB to banks – the year-on-year rate of change in the share of CNB loans granted to banks expressed in kunas.

16) Foreign trade – the year-on-year rate of change in the quotient of total exports of goods and total imports of goods; exports of goods and imports of goods expressed in US dollars.

17) Real kuna/euro exchange rate – the real exchange rate of the kuna against the euro [calculated as a quotient of the multiple of nominal exchange rate and the core retail price index (base = 1996) and the core harmonized index of consumer prices (base = 1996)].

18) M1a – the rate of change in money supply M1a, which includes currency outside banks and demand deposits with banks increased by the demand deposits of central government held with banks; M1a expressed in kunas.

19) Short-term debt/GDP – the year-on-year rate of change in the share of the short-term debt at the end of a month in the twelve-month GDP moving sum (interpolated from a three-month to a monthly level using the cubic spline method); short-term debt (which includes debt in the form of money market instruments issued by the government, banks and other sectors in the international market, short-term commercial loans of the government and other sectors, short-term loans of the government and other sectors, debt based on currency and bank deposits and short-term bank debt) and GDP expressed in US dollars.

20) Total capital inflow – the year-on-year rate of change in capital inflows, including foreign direct investment in Croatia, liabilities based on portfolio investments and liabilities based on other investments, expressed in US dollars.

21) Imports – the year-on-year rate of change in total imports of goods expressed in US dollars.

22) Money supply, M1 – the year-on-year rate of change in money supply expressed in kunas.

23) Net usable international reserves – the year-on-year rate of change in net usable international reserves (the difference between foreign assets and the sum of foreign liabilities, allocated required reserves, and CNB bills in foreign currency) expressed in euros.

24) Gross international reserves – the year-on-year rate of change in gross international reserves (consisting of special drawing rights, reserve position in the IMF, gold, foreign currency and deposits with foreign banks, and bonds and debentures) expressed in euros.

25) Exports – the year-on-year rate of change in total exports of goods expressed in US dollars.

26) Real money market interest rate – the difference between the nominal money market interest rate (interest rate on overnight loans) and inflation measured by the year-on-year rate of change in the retail price index.

27) Foreign liabilities of monetary institutions – the year-on-year rate of growth in foreign liabilities of the CNB and banks expressed in kunas.

28) Nominal lending interest rate/deposit interest rate (with a currency clause) – ratio between nominal interest rates on kuna loans with a currency clause (overall average of interest rates on short-term and long-term kuna loans with a currency clause granted to retail and corporate clients) and nominal interest rates paid on kuna deposits with a currency clause (overall average interest rate on short-term and long-term sight deposits and time deposits with a currency clause).

29) Real effective exchange rate (retail prices) – the index of the real effective exchange rate as a weighted geometric mean of bilateral kuna exchange rates adjusted for corresponding indices of relative prices (ratio of the price index in the countries that are Croatian trading partners, using the harmonized index of consumer prices for EMU member countries, and domestic prices, using the retail price index).

30) Deviation of the real effective exchange rate from the trend – deviation of the real effective exchange rate from a linear trend.

31) Total capital outflow – the year-on-year rate of change in total capital outflow, including foreign direct investment, funds used in portfolio investment abroad and funds used for other investments abroad expressed in US dollars.

32) Industrial production – the year-on-year rate of change in the industrial production index.

33) Reserve money, M0 – the year-on-year rate of change in reserve money, M0.

34) Net usable international reserves/M4 – the year-on-year rate of change in the share of net usable international reserves in M4 expressed in kunas.

35) GDP (real) – the year-on-year rate of real GDP growth expressed in kunas (interpolated from a three-month to a monthly rate using the cubic spline method).

36) M2/net reserves – the year-on-year rate of change in the share of M2 in net usable international reserves expressed in kunas.

37) Bank deposits – the year-on-year rate of change in broad money (difference between M4 and cash) expressed in kunas.

38) Nominal lending interest rate/deposit interest rate – ratio between the nominal interest rate on kuna loans without a currency clause (overall average interest rate on short-term and long-term kuna loans without a foreign currency

clause granted to corporate and retail clients) and the nominal interest rate paid on kuna deposits with a foreign currency clause (overall average interest rate on short-term and long-term kuna deposits without a currency clause held by retail and corporate clients and interest rates on deposits in giro accounts and current accounts).

# Appendix 2
# Overview of Movements in the Most Reliable Signalling Indicators of a Currency Crisis

**Figure 5** Current Account Balance/GDP

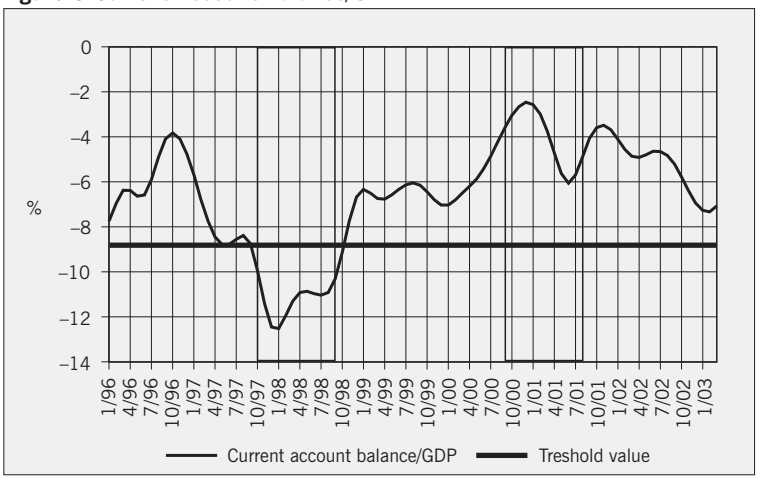



**Figure 6** Balance of Public Finances/GDP

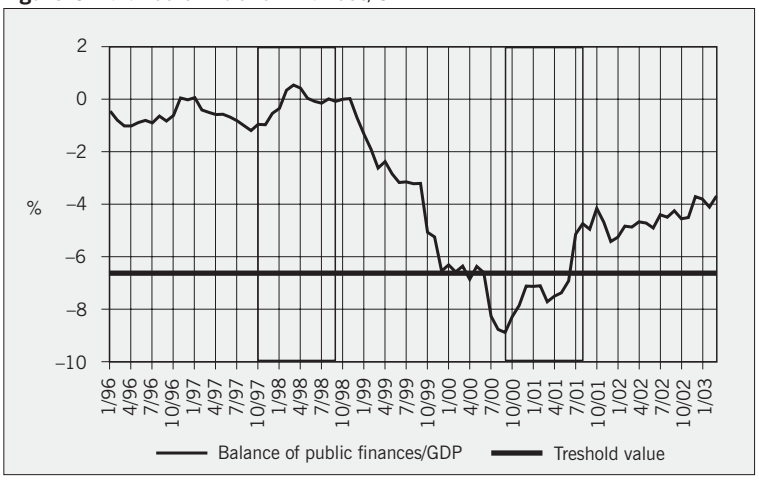



**Figure 7** Inflation

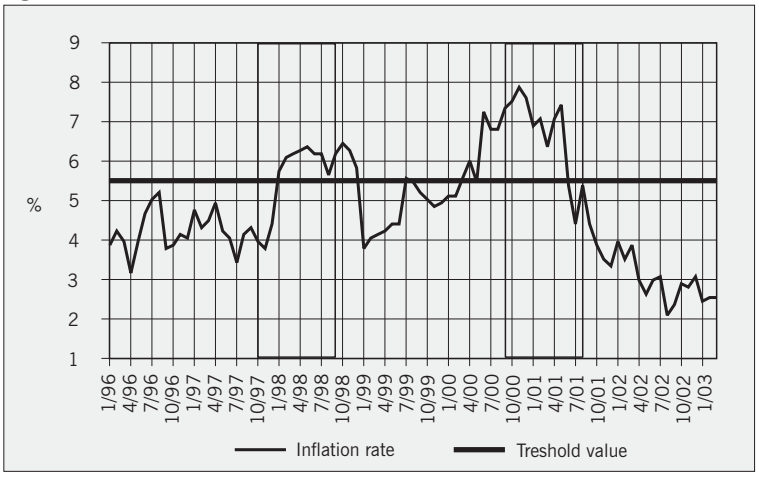


**Figure 8** Freely Available Bank Reserves/Total Bank Assets

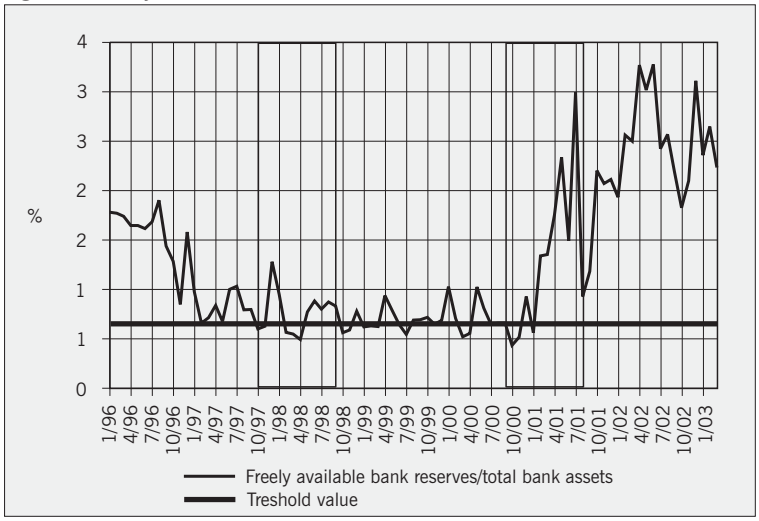



**Figure 9** External Debt

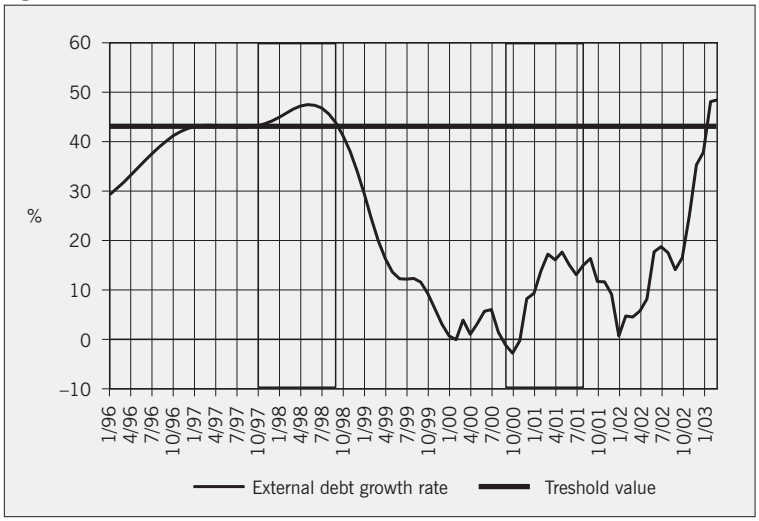



**Figure 10** Loans

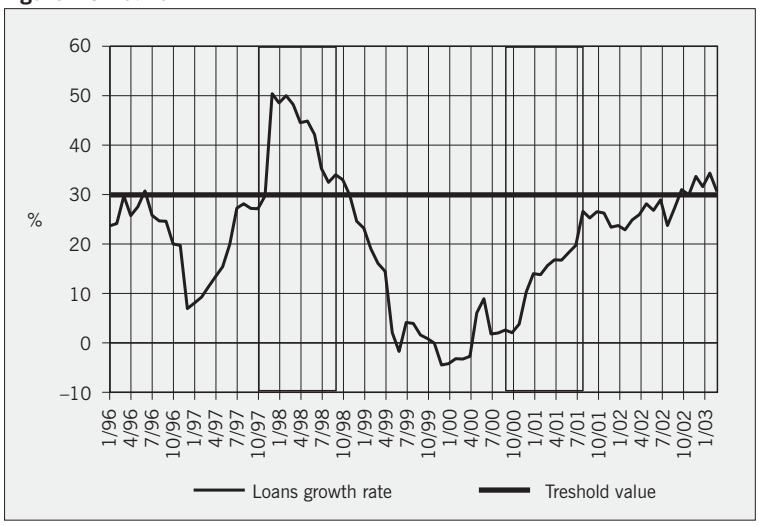


**Figure 11** Foreign Assets/M4

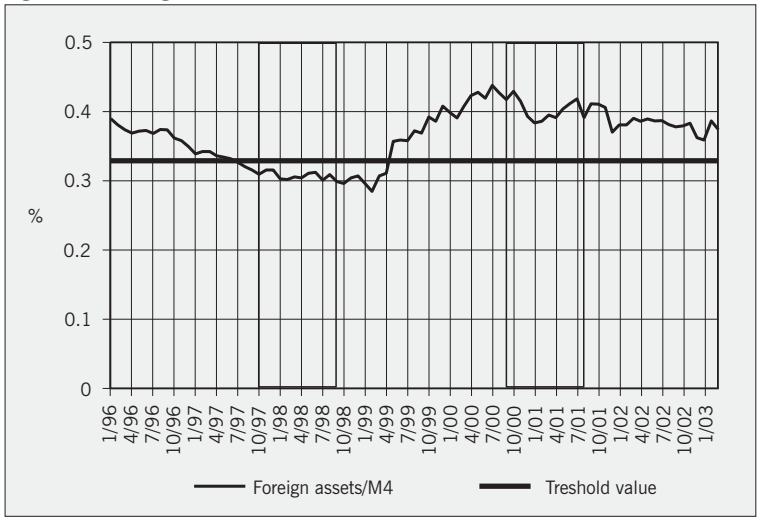



**Figure 12** Multiplier m2

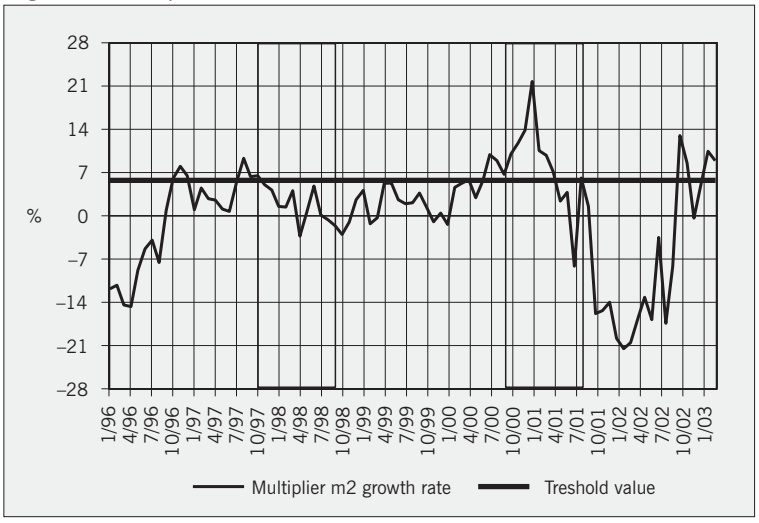
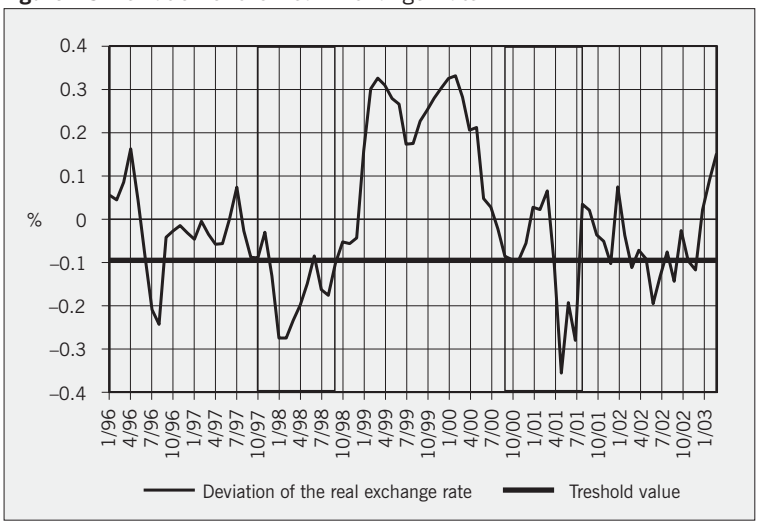



**Figure 13** Deviation of the Real Exchange Rate



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In its periodical publications *Working Papers, Surveys and Discussion Papers*, the Croatian National Bank publishes scientific and scholarly papers of the Bank's employees, visiting scholars, and other associate contributors.

After the submission, the manuscripts shall be subject to peer review and classification by the Manuscript Review and Classification Committee. The authors shall be informed of the acceptance or rejection of their manuscript for publication within two months following the manuscript submission.

Manuscripts are submitted and published in Croatian and/or English language.

Manuscripts submitted for publication should meet the following requirements:

Manuscripts should be submitted in magnetic or optical storage media (3.5-inch floppy, ZIP, CD) accompanied by three printed paper copies. The acceptable text formats are Word for Windows/Mac. RTF code page 437 or 852 format is preferred.

Diskettes should be labeled with the type of the word-processor and database used, as well as with the name of the author.

The first page of the manuscript should contain the article title, first and last name of the author and his/her academic degree, name of the institution with which the author is associated, author's co-workers, and the complete mailing address of the corresponding author to whom a copy of the manuscript with requests for corrections shall be sent.

Additional information, such as acknowledgments, may be included in the first page. If this information is extensive, it is preferred to incorporate it within the text, whether at the end of the introductory section or in the special section preceding the list of references.

The second page should contain the abstract and the key words. The abstract is required to be explicit, descriptive, written in third person, consisting of not more than 250 words (maximum 1500 characters). The abstract should be followed by maximum 5 key words.

A single line spacing and A4 paper size should be used. The text must not be formatted, apart from applying bold and italic script to certain parts of the text. Titles must be numerated and separated from the text by a double line spacing, without formatting.

Tables, figures and charts that are a constituent part of the paper must be well laid out, containing: number, title, units of measurement, legend, data source, and footnotes. The footnotes referring to tables, figures and charts should be indicated by lower-case letters (a,b,c…) placed right below. When the tables, figures and charts are subsequently submitted, it is necessary to mark the places in the text where they should be inserted. They should be numbered in the same sequence as in the text and should be referred to in accordance with that numeration. If the tables and charts were previously inserted in the text from other programs (Excel, Lotus…), these databases in the Excel format should also be submitted (charts must contain the corresponding data series).

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