ANALYSES AND RESEARCH *

Publ.: Financial Stability Report 2012, Central Bank of Armenia, 2013, pp. 57-140

Central Bank of Armenia Working Paper, Number WP 08/09-01E

EARLY WARNING SYSTEMS FOR PREDICTING CURRENCY CRISES IN ARMENIA

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EXECUTIVE SUMMARY

On the brink of the global financial and economic crisis, developing countries, Armenia among them, were enjoying enormous economic progress, based on huge foreign currency inflows. Against the background of the global crisis, the termination of such flows stirred a wave of currency crises since autumn of 2008, which was also showed up in Armenia. In this study we will attempt to identify leading indicators for predicting currency crises in Armenia (as well as in CIS and CEE countries) and to build applied early warning systems (EWS) by using the conventional Signaling approach and relatively new Classifications tree models. As a result, it was found out that almost all the indicators discussed had good forecasting properties for Armenia's economy, and among them one may especially point out such leading indicators as budget deficit, credit, inflation, foreign debt and bank assets indicators. At the same time 9 out of 24 variables discussed come in to have the best leading properties, signaling at least with 3 quarters' advance. Addressing the issue of the causes of crises it was revealed that most crises observed in developing countries in Europe had been attributable to the problems of budget deficit and excess financing: self-fulfilling crises also hold a significant share. The models (including combined ones) developed in this paper are remarkable for their high forecasting power and good properties while the model, based on a CART methodology, with its main forecasting properties even surpasses all other types of models for EWS available in the literature. In addition, all models best predicted the currency "crisis" in Armenia in March of 2009, so they can be used in forecasting currency and financial crises in Armenia (and other countries in the region as well).

In a crisis you are a hostage of your past...
Guillermo Calvo

INTRODUCTION

Predicting currency crises has a huge importance for both macroeconomic policymakers and financial market participants. However, while participants of the financial market pursue the realization of their own interests, the policymakers need this to respond to the problem in a timely and properly manner. The devastating economic consequences of currency crises call for the need to mobilize efforts in order to prevent them. Therefore, in this context, the need for some mechanism or system that would facilitate in time identification of the problems typical to a country, prediction of the likelihood of emergence of crises and taking appropriate actions becomes inevitable.

* *The author's views may not coincide with the official position of the Central Bank of the Republic of Armenia.*

Since the 1970s, this issue has been the focal point of economists and researchers. But in the aftermath of the waves of three major crises especially during the 1990s, there has been an increased interest in developing early warning systems (EWS) in order to predict financial and currency crises. To this end, there have been carried out a bunch of analytical work whereby through taking various traditional and modern approaches it was attempted, to pinpoint the causes of crises and the problems associated with building signaling models involving countries, regions and various groups of developing countries.

In the first decade of 2000s, the developing countries, the Republic of Armenia among them, tracked an enormous economic progress, mostly owing to influx of foreign financial resources and huge foreign currency inflows resulting from a favorable environment in world commodity markets. Certainly, in the wake of massive financial inflows, the domestic credit growth, coupled with strengthening real estate market and an unprecedented rise in asset prices, expanded foreign currency liabilities of the private sector and banks. Although it also improved current accounts of balance of payments, and resulted in mounted international reserves, the developing countries were starting to discern symptoms of economy overheating as their currencies began appreciating considerably. Therefore, in the above-mentioned circumstances, an abrupt reduction of the inflow of foreign currency funds proved to be a key concern associated with exchange rate developments. Undoubtedly, the subsequent wave of currency pressures starting in autumn of 2008, which quickly spread over to nearly all the developing countries, points to the statement aforementioned. Although certain macroeconomic weaknesses were attributable to some countries before the crisis, this one however was different from previous ones for the developed world was the epicenter of the crisis, whereas the developing countries faced it as an external shock, unlike previous crises that had started out because of short-sighted economic policies in these countries.

It should be noted that this particular project for crisis prediction for the Armenian economy started back in early 2008. This was based on a number of trends observable in the country in recent years, which were broadly in line with crisis situations previously seen in other developing countries. In the aftermath of sharp currency exchange rate depreciation on March 3, 2009, however, designing early signaling systems became imperative for Armenia in order to detect the origins of this depreciation and prevent such adverse developments in future. The main achievments of the project has been summarized in this paper developed already in 2009.

This work is by nature the first study which addresses the problems of predicting the currency crises (pressures) in Armenia. It has an inclusive account of a bunch of countries in Central and Eastern Europe and some CIS countries which had not been dealt with in other analytical works related to the problems of currency crises. This is, therefore, another interesting aspect of this work. In addition, this analysis is perhaps among the first ones that covered, although partly, the 2008-2009 crises. Finally, the most valuable input here is that it applies one of the most recent approaches in modeling: thus parallel to the traditional signaling approach, the main focus of this paper is on the Classifications and Regressions Tree (CART) method, which is almost non-existent in literature on currency crises prediction and EWS.

The first chapter will give an outline of theoretical models for prediction of currency crises; the second chapter will describe the main steps for building EWS, including the definition of currency crises, the choice of leading indicators and the formulation of applied models and approaches. The third chapter will refer to the developed EWS for prediction of currency crises in Armenia.

CHAPTER 1

Theoretical basis for forecasting currency crises

The theoretical literature on the issues of crisis prediction offers many different models that are designed to explain what causes the currency crises. These models can be conventionally classified into three groups. First generation models (speculative attack models) were created to explain the currency crises in Latin American countries in 1970-1980s (Mexico in 1973-1982, Argentina in 1978-1981). These show that currency crises are the result of speculative attacks, which thus occur due to the implementation of monetary and fiscal policies inconsistent with exchange rate targeting. Second generation models successfully explain the crises in Europe and Mexico in 1990s, and consider self-fulfilling and multiple equilibria as the features inherent to currency crises. Third generation models attribute the phenomenon of banking troubles and contagion effects as causes of currency crises. These

models are designed to explicate the Asian crisis that has occurred in the period 1997-1998. There are also many other models that explain the various phenomena and manifestations of the crisis, yet remain outside the suite of traditional "generation" models.

First generation models

Until the early 1990s, the main theoretical ideas explaining the origination of currency crises were summed up in the first generation models, which considered the crisis as a sudden and sharp decline in the level of international reserves, abandonment of the existing exchange rate regime or simply currency devaluation resulting from speculative attacks. These models were called to explain the reasons of such speculative attacks.

The forefather of first-generation models was Krugman (1979), for whom the model of attacks to manageable gold prices by Salant-Henderson (1978) served as a pre-model. Krugman's input on behalf of the first-generation models is the explanation of the abandonment of the existing exchange rate regime as a consequence of monetary and fiscal policies inconsistent with the issue of exchange rate targeting and a feeble macroeconomic environment. According to the logic behind the Krugman model, the main cause for the currency crises and speculative attacks lies in the surpassing growth of domestic credit to finance the budget deficit or to support the banking system. Under the implication of the model that the government does not have access to capital markets or cannot endlessly finance its deficit through foreign funds leaves it nothing but to monetize the expenditures. Such an increase in money supply exerts pressures on interest rates, while in the face of interest rate parity condition this will result in a capital outflow, which will then lead to a gradual reduction in international reserves. In addition, the government's expansionary policy brings about an excess demand in the economy; this leads to deterioration of current account and balance of payments which are financed at the expense of reserves. Finally, the level of international reserves reaches some threshold value, after which the start of speculative attacks causes depletion of the rest of the reserves and collapse of the monetary system.

Now let us draw an outline of the simplest first generation cornerstone model. The model is built for a small open economy which maintains a fixed exchange rate regime.

The condition of domestic money market equilibrium is given in the following form:

$$m - p = -\alpha(i),\ \alpha > 0 \tag{1}$$

Where: m *is monetary base,* p *is domestic price level,* i *is domestic currency interest rate (here and now all indicators, except interest rates, are expressed in logarithms).*

The domestic money supply is backed by the central bank assets – domestic credit (d) and international reserves (r). This in a simplest linear form can be:

$$m = d + r \tag{2}$$

Domestic interest rates and prices are subject to international arbitrage conditions: that is the conditions of purchasing power parity (PPP) and uncovered interest parity (UIP) are hold:

$$p = p^* + s \tag{3}$$

$$i = i^* + \dot{s} \tag{4}$$

Where: p^* *and* i^* *are respectively prices and interest rates of other countries,* S *is exchange rate (growth means depreciating local currency),* $\dot{s}$ *is the difference between the expected and actual levels of the exchange rate (expected change).*

In fact, in the fixed exchange rate regime the money market equilibrium is established by adjustment of reserves whilst in the free-floating regime, by adjustment of exchange rate.

Therefore, assuming that the exchange rate is fixed $\dot{s} = 0$ and $i = i^*$, and i^* and p^* are constant, from equations (1)-(4) it follows that:

$$r + d - p^* - \bar{s} = -\alpha(i^*) \tag{5}$$

where: $\bar{s}$ *is the fixed exchange rate level.*

For a small open economy which carries on a fixed exchange rate policy, assuming that the deficit financing credit expansion is growing at a constant μ rate, international reserves will fall down at the same $\dot{r} = -\mu$ rate. It is obvious that in this case the country's reserves will vanish eventually while the country will found itself in a crisis situation.

The most important feature of this generation models, which is absent from the other models, is the ability to predict the right timing of speculative attacks hence currency crises. To this end, it is necessary to incorporate in the model the so-called "shadow exchange rate", the $\tilde{s}$, which is a floating exchange rate that will occur in the market as a crisis emerges as a result of speculative attacks. Assuming that in the crisis aftermath the country's foreign reserves come close to 0(it may not necessarily have to be that way, which of course will affect the setting of the shadow exchange rate level, however this is not presented here for simplicity), and $i^* = p^* = 0$, the post-crisis money market equilibrium condition will be expressed through:

$$d - \tilde{s} = -\alpha(\dot{\tilde{s}}) \tag{6}$$

After the onset of the crisis the credit growth at the μ rate, under the condition of equilibrium, will mean depreciation of the exchange rate at the same rate; so the exchange rate will be:

$$\tilde{s} = \alpha\mu + d \tag{7}$$

It turns out that the shadow exchange rate depends on the volume of lending, so there is a level $d = d^A$ in which speculative traders predicting a currency crisis and driven by the lure of getting super profits as a result of eventual exchange rate depreciation rush into speculative attacks. . It can be shown that this point complies with the condition $\tilde{s} = \bar{s}$.

Two phenomena observable during the speculative attack keep the money market in equilibrium. These are: 1/ the money supply reduces to the extent of the attack Δr , and 2/ in the crisis aftermath, the μ depreciation of the exchange rate, under interest rate parity, presumes that much increase of interest rates (which reflects future depreciation expectations) at the time of speculative attack, which leads to the reduction of demand for domestic currency. Therefore, the money market equilibrium will be maintained, if $\Delta r = -\alpha\mu$. Since the domestic credit is characterized as $d_t = d_0 + \mu t$, the reserves will be expressed as $r_t = r_0 - \mu t$. At the time of crisis (T) the reserves approach to 0, and the crisis condition is characterized as follows: $-\Delta r = r_0 - \mu T = \alpha\mu$. So, it turns out that:

$$T = \frac{r_0 - \alpha\mu}{\mu} \tag{8}$$

which is to say, the bigger the initial stock of the reserves and the slower the credit expansion, the longer it takes for the fixed exchange rate to last.

The simplest model presented[1], despite a series of simplest assumptions, reflects the logic behind the first-generation models. Many authors after Krugman (Flood and Garber, Connolly and Taylor, Calvo and others) also referred to this, making essential modifications discussing the uncertainty of speculative attacks, the sterilization policy, the credibility of exchange rate regime, the price rigidities, the behaviors of prices of tradable goods, current account and real exchange before the crisis etc.

To summarize, first-generation models made a number of important contributions to the development of theories about currency crises. These include:

- currency crises are predictable,
- macroeconomic indicators and other fundamental factors behave in a typical way before crises; these factors are mainly pertinent to exchange rate and balance of payments models and are amazing indicators from the crisis prediction standpoint,
- crisis may occur at a time when international reserves are not yet fully exhausted,

[1] More details about first-generation models with the main supplements made thereto are available in the paper by Flood, Marion (1997).

- central banks may adopt a fixed exchange rate regime provided they have sufficient foreign exchange reserves,
- central bank reserves need to be able to cover its entire liabilities, especially in economies with a higher dollarization rate[2],
- with concern over monetary stability under high mobility of capital flows, the central bank's sterilization policy steered to foreign exchange rate stability is ultimately doomed to failure and the currency crisis is inevitable, if speculative traders predict the authorities' intentions[3] (in fact, these structural models touch the phenomenon of the "impossible trinity").

Second generation models

The first generation models failed to explain the European Monetary System's crisis in the period 1992-1993. Before the crisis, the European countries did not have any significant economic difficulties, used to hold sufficient levels of international reserves, nor had the economic policy brought about any considerable challenges. Therefore, the fundamental factors distinguished under crisis theories at hand were not able to explain the crisis. This served a basis for the design of new models, which were conventionally called the second generation models. The founder of first-line models of this generation is Obstfelde (1986, 1995). The main properties inherent in these models include as follows: 1/ the government plays an active role in the economy and seeks to maximize its own objective function, 2/ there comes a phenomenon of circularity, which leads to the multiple equilibria.

These models point to the problem of duality of the government's objective function as to whether to maintain the fixed exchange rate or trade its benefits in for other purposes, such as employment or economic growth. In particular, the fixed exchange rate regime could be abandoned if the government realizes that the economic benefits of sticking to it (monetary stability and credibility) are not outstripping undesired outcome generated in terms of other economic variables (unemployment, troubles in the banking system, a large public debt). Therefore, any policy option contains some alternative, that is, the policy itself grows into an endogenous factor.

Economic agents make their decisions on speculative attacks not on a basis of existing discrepancies between current macroeconomic indicators and current regime but on the expectations of these incompatibilities just after the attack. Such expectations of speculators influence on different macroeconomic indicators and, therefore, on the government's choice of the objective function. This is where the phenomenon of circularity shows up, which, often coupled with non-linearity behavior of the government, results in the condition of multiple equilibria. At one point of the equilibrium, in the face of favorable anticipations, there are neither speculative attacks nor crisis, since at the time of attacks the agents do not win but they do not lose either, while one will see attack and crisis taking place at the other point of the equilibrium. In the latter case, as a result of speculative attack, by virtue of an alternative choice of its objective function, the government eventually abandons the fixed exchange rate regime, which is what justifies the agents' expectations. In fact, multiple equilibria tend to trigger self-fulfilling crises.

As for the problem of multiple equilibria, there is a diversity of well-known authors trying to figure out the factors that determine the existence of it. Transition from one equilibrium state to another occurs when the current speculative market expectations are coordinated and steered to achieve that goal, because otherwise the agents alone (individually) could not lead to any crisis. The multiple equilibria in this case are determined by common knowledge (information) on fundamentals, under which circumstance the simultaneous change in everybody's expectations can provide for the transition from one equilibrium state to another. Turning to the conventional wisdom on economy, Morris and Shin (1995) note that injecting some amount of uncertainty into the information on these fundamentals, will result the equilibrium outcome to be a unique one[4], since, in uncertainty, every speculative trader will think attacks is the best option in consideration of other agents' possible awareness. Krugman (1996) believed multiple equilibria were existent only if the knowledge of the fundamentals is incorrect or unclear[5], otherwise the equilibrium would be the one because if it is clear that there is discrepancy

[2] *Eichengreen, Rose, Wyplosz (1996), p. 8.*
[3] *Flood, Marion (1997), p. 11.*
[4] *Flood, Marion (1997), p. 21.*
[5] *Eichengreen, Rose, Wyplosz (1996), p. 10.*

between available fundamentals and the fixed exchange rate regime that would definitely lead to an equilibrium state, namely a speculative attack and crisis.

Next important feature of the second generation models is attributed to the role the fundamentals have in them. Unlike the first generation models, here the causality between the fundamentals (unemployment, the situation in the banking system, government debt, etc.) and crises is dual-sided, which is reflected in demonstration of multiple equilibria and self-fulfilling crises as attributable to the phenomenon of circularity. In general, the second generation models have two diametrically opposite views on fundamentals. Some of them attach great importance to a healthy macroeconomic environment as a way to battle crises, noting that albeit it is not possible to unmistakably reveal the source of the crisis, however, one may be able to determine which countries are most vulnerable to it. According to these models, in the event of various upheavals and changes in the macroeconomic situation the country's authorities would be able to waive their exchange rate policy.

Another suite of the models falling within this generation excludes at all the role of fundamentals in predicting currency crises. They believe that the crisis may arise as a result of a speculative attack, which may be due to two factors: the herd effect and the contagion effect. The latter appears in the second generation models within the mechanism of multiple equilibria, in a form of self-fulfilling crisis arisen as a result of expectations due to crises in other countries. For this reason it is often called a spillover effect, so that it comes distinguishable from the contagion effect[6]. It is worth mentioning that, the contagion effect per se refers to situations of instability observable in one country as a result of the crisis emerged in another country which is due to economic and financial relations that exist between the two countries in question (see details in the section "Third generation models").

Thus, the second generation models mostly withdraw from crisis explanation approaches based on fundamentals and stress the role of expectations at the core of the crises. Furthermore, in the face of immeasurability of the coordination of expectations and the loss of confidence, it is impossible to develop crisis forecasting models based on fundamentals. In such circumstances though, the best way to combat crises not justified by macroeconomic indicators is to increase credibility of central banks, because, if there is a belief that after the crisis the central bank will implement a policy which implies an exchange rate appreciation, it will eliminate the motivation of the agents to achieve a self-fulfilling crisis and own benefits as a result of speculative attacks[7].

Third generation models

The first and second generation models were mainly focused on the factors explaining the nature of the macroeconomic environment and policy, without regard to such key factors as situation in the financial system and the imperfections of the markets. The latter lay under the Asian currency crises of 1997-1998 and existing theories, therefore, were not able to explain their causes. As a result, new, a third generation models, came in to address the relationship between financial, banking and currency crises as well as the effect of contagion. Distinguishing the authors of the models of this generation is rather difficult but basically they are Chang and Velasco (1998), Kaminsky and Reinhart (1999), and Gerlach and Smets (1994).

In general, these models are divided into three major groups that address, accordingly, three different causes of crises. The first group of theories emphasize on the weaknesses in the banking system (enormous foreign debt, troubles with balance sheet positions, moral hazard provoked by bogus government guarantees, weak supervision, etc.) that lead to banking and currency crises. The link between banking and currency crises is expressed in several ways. Government measures to bail out troubled banks as a lender of last resort may lead to a situation where the level of budget deficit is no longer controllable, which could bring about a currency crisis straightforward (first generation models). The causality between banking and currency crises may also pace the opposite direction: when high foreign currency risk becomes increasingly inherent in the banking system due to huge short-term foreign debt, currency crises may bring in serious difficulties in the banking sector. In fact, although Kaminsky and Reinhart (1999) revealed a dual-sided causality, the banking crises yet used to go before the currency crises[8].

[6] *Esquivel, Larrain (1998), p. 5.*
[7] *Eichengreen, Rose, Wyplosz (1996), p. 11.*
[8] *Kaminsky, Reinhart (1999), p. 491.*

The second group of this generation models considers the herd effect of banking and financial system agents as the main cause for currency crises. When faced with certain problems, these agents, massively following each other, seek safe haven in foreign currency assets.

The third group of models refers to perhaps the most important contribution of this generation theories, i.e. the effect of contagion. Approaches that explain the contagion effect are different in literature, yet Gerlach and Smets (1994) were the authors who have taken profound systematic theoretical approach to this problem. They view existing trade and financial linkages between countries as the mechanism for transmission of the contagion. Thus, if there has been a depreciation of the real exchange rate due to a crisis in a country, this would imply an improvement of external competitiveness of that country, which would in turn lead to deterioration of the balance of payments and reduction in reserves hence a currency crisis in a partner country. On the other hand, exchange rate depreciation in the countries of the region would have a restrictive impact on particular country's imports and consumer prices and, in an outcome, excess cash funds generated as a result of reduction in demand for money would be channeled to the foreign exchange market.

The financial channel of transmission of contagion is demonstrated through problems lender countries encounter as a result of non-performance of external liabilities of financial intermediaries in borrower countries.

The next channel of transmission of contagion is determined by countries' vulnerabilities to similar external shocks as well as creation and materialization of similar expectations in a country in case a crisis emerges in another country that shares common structural specificities.

The next crisis explanation models are not classified among any generation models: the major one of them views political and structural factors closely linked with macroeconomic variables and expectations as determinants of currency crises.

Summing up the review of theories regarding currency crises, let us note that, as Krugman (2001) said, the future – the fourth generation – models will incorporate a more general framework and will address financial crises, while other financial assets will play the central role in them[9]*.*

CHAPTER 2

Building early warning systems

An early warning system (EWS) is called to identify and predict currency crises by looking at the developments of variables known from crisis theories. EWS shall be construed to involve a clear definition of the crisis and a practical prediction mechanism in place. Therefore, for currency crises, building EWS will be taking a number of steps, as follows:

- definition and evaluation of currency crisis,
- choice of explanatory or leading variables (indicators),
- choice of the period under review and/or the group of countries,
- choice of the forecast horizon,
- choice of the type and construction of a forecasting model,
- evaluation of the predictive power and properties of the model.

The definition of currency crisis

The currency crisis, which is often referred to as balance of payments crisis, is broadly defined as an episode in which the value of the currency changes abruptly in a short period of time[10], which results in a full or partial loss of exchange or store of value functions . In a narrower sense, the currency crisis is the official devaluation of the currency or a shift to a floating exchange rate regime. This definition, of course, refers to the fixed exchange rate regime. Therefore, the most common definition for currency crisis is the situation when speculative attacks lead to a sharp depreciation of the currency, reduction in international reserves or the two developments altogether. The definition includes both successful and

[9] *Tinakorn (2002), p.5:*
[10] *Burnside, Eichenbaum, Rebelo (2007), p. 1*

unsuccessful attacks, and is applicable to both fixed and floating exchange rate regimes. It should be mentioned that the currency crises are an integral part of financial crises but they can emerge both separately and in concurrence with other crises (banking, debt, etc.).

In practice, there are a lot of approaches for defining currency crises (see Appendix 1). In general, they can be discussed in two major groups: in the first group the crises are related to the segments of upmost pressure based on some *continuous* index, therefore such index also reveals the intensity of the crisis; and in the second group, which is the most common in literature, the crises appear as dual discrete variables, in the form of 0/1 (tranquil period/crisis). The next problem, which deals with distinguishing the crisis episodes in practice, is determined by the choice of factors that provide for the definition of crises – whether to consider the dynamics of the nominal exchange rate (the rate of depreciation) alone or to take other factors into consideration as well. According to one of the above-mentioned definitions of currency crises, pressures in the currency market are discernible through either exchange rate depreciation or reduction in the central bank's foreign exchange reserves. In essence, the change in international reserves are not fully explained by central bank interventions in order to keep the stability of the exchange rate, since the reserves may change for different reasons – as a result of reassessment, interest income, etc. In addition, for the exchange rate regulation, there could be used so called "hidden foreign exchange reserves transactions"[11], such as credit lines (Ireland, 1992-1993), derivatives transactions (Thailand, 1997), issuance of foreign currency debt securities (Brazil, 1998-2000) and so on, which are not reflected in the change of reserves. Theoretically, the volatility of reserves should be minor – if not equal 0 – in a floating exchange rate regime. This does not however mean that under this regime the authorities are not capable of safeguarding the exchange rate from speculative attacks. This can be carried through foreign exchange market interventions but, according to the view by Calvo and Reinhart (2000) the interest rate policy as an instrument of smoothing exchange rates is becoming increasingly applicable[12]. One example could be a particular case of Mexico where, on the back of the Russian crisis in 1998, the level of interest rates had doubled to 40%[13]. However, the effectiveness of the interest rates calls for an exercise of the functioning of interest rate channel or the interest rate parity[14].

The above discussion makes it clear that taking the dynamics of exchange rate alone as an identifier of a crisis is not enough: the change in reserves and interest rates, or at least one of them needs to be considered along with the exchange rate. It should be noted that interest rates are not often considered in the literature due to the lack of data.

We also among various definitions provided in Appendix 1 selected those ones , which consider reserves and interest rate flows in addition to exchange rate volatilities while trying to identify the crises episodes.

The most common approach in literature is the usage of the exchange market pressure index as an instrument for identifying crisis episodes. The authors of the index are Girton and Roper (1977) who used it in a completely different context (evaluation of the link between the market pressure and the monetary policy)[15]. Subsequently, the index gained popularity in the literature on currency crisis assessment and building of early warning systems. Initially, the index was being constructed by the use of exchange rate and reserves indicators only but later on Eichengreen, Rose, Wyplosz (1996) suggested including the interest rates as well.

The main principle of constructing the exchange market pressure index states that none of the variables have a dominant impact on the value of the index. Therefore, the weights of the components are selected so that their conditional volatilities are equal. The index and its weights are calculated in the following process:

We assign index components, i.e. variables A, B, C[16].

The currency pressure index will be:

$$I = \alpha_1 A + \alpha_2 B + \alpha_3 C$$

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[11] *Calvo, Reinhart (2000), p. 16.*
[12] *Calvo, Reinhart (2000), p. 28.*
[13] *Reinhart, Rogoff (2004), p. 27.*
[14] *The choice of the nominal interest rate can be founded by an argument that the current exchnage rate, under the hipothesis of rational expectations, includes the discounted value of future inflationary expectations, while the current nominal interest rate is also shaped in the light of future inflationary expectations; therefore at the time the exchange rate and interest rate move according to the same principle: the nominal interest rate, inclined towards the future inflation, affects the current level of the exchange rate.*
[15] *Girton Lance, Roper Don (1977), p. 541.*
[16] *Let us not refer to the specific look and signs of the variables but accept the assignments as they are.*

According to the principles of index construction, the weights α_1, α_2, α_3 are selected so that the volatilities of the weighted values of components are equal while the sum of the weights is 1:

$$\begin{cases} \alpha_1^2 * \text{var}(A) = \alpha_2^2 * \text{var}(B) = \alpha_3^2 * \text{var}(C) \\ \alpha_1 + \alpha_2 + \alpha_3 = 1 \end{cases}$$

where: var() *is the variance of the variable.*

By taking square root from the first equation and solving the system with respect to α_1, α_2, α_3 we will get:

$$\begin{cases} \alpha_1 = \dfrac{\sigma_B \sigma_C}{\sigma_A \sigma_B + \sigma_B \sigma_C + \sigma_A \sigma_C} \\ \alpha_2 = \dfrac{\sigma_A \sigma_C}{\sigma_A \sigma_B + \sigma_B \sigma_C + \sigma_A \sigma_C} \\ \alpha_3 = \dfrac{\sigma_A \sigma_B}{\sigma_A \sigma_B + \sigma_B \sigma_C + \sigma_A \sigma_C} \end{cases}$$

where: σ *is the standard deviation of the respective variable.*

Since we are primarily interested in the dynamics of the index rather than its value, after some arrangements (multiplying several times by positive numbers) we will get:

$$I = \frac{1}{\sigma_A} A + \frac{1}{\sigma_B} B + \frac{1}{\sigma_C} C$$

Based on this general profile of the foreign exchange market pressure index, we built a number of sub-type indices where monthly change in nominal effective exchange rate, the U.S. dollar / Armenian dram exchange rate, monthly change in the Central Bank's net foreign assets (excluding the privatization account and corresponding accounts of banks in foreign currency) and the difference between domestic and external interest rates were viewed as elements[17]. In the outcome, indices we constructed and discussed are as follows:

Version 1: based on the U.S. dollar / Armenian dram exchange rate:

$$EMP = \frac{1}{\sigma_e} \%\Delta e + \frac{1}{\sigma_i} (i - i^*) - \frac{1}{\sigma_r} \%\Delta r$$

Version 2: similar to version 1, by the use of the nominal effective exchange rate.

Version 3: the first version, excluding interest rates:

$$EMP = \frac{1}{\sigma_e} \%\Delta e - \frac{1}{\sigma_r} \%\Delta r$$

Including the above-mentioned variables based on the table provided in the paper by Hawkins and Klau (2000)[18] (see Appendix 1) an option of the currency market pressure index was constructed, similar to the one discussed in the above-mentioned paper, as well as a version of it with normalized variables[19]. This version of the index has undergone some modifications as well: at first the threshold values of indicators as provided in the table were revised based on the study of distribution of relevant series in Armenia and the index was built.. Then, in another version, assuming equal distribution of series in the groups, an index was built in consideration of percentiles as marginal (threshold) values. In the outcome, we had the following versions:

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[17] Armenia's money market interest rates were taken as domestic interest rates and the U.S. Federal Funds rate as external interest rates. We have built indices too, using the difference of real interest rates. However, after having considered a couple of variants of calculation of real interest rates, the results proved non-satisfactory, so they are not presented here.

[18] Hawkins, Klau (2000), p. 26.

[19] The normalization was performed by calculating the deviation of series from their means relative to the standard deviation of the indicator.

Version 4: according to the table provided in the paper by Hawkins and Klau (2000) (see Appendix 1).

$$EMP = W_1 \cdot xrm + W_2 \cdot xra + W_3 \cdot r + W_4 \cdot res$$

Version 5: similarly, with appropriate normalization, by taking as thresholds {-1.5, -0.5, 0.5, 1.5} values for all variables.

Version 6: after histogram study of the distribution of Armenian series, we had the 4 modified conditional thresholds in the table[20].

Version7: using a version of the table with modifications based on equal percentiles {20, 40, 60, 80}[20].

The indices built according to the versions shown above are continuous series by nature (this is especially true for the first three variants) and point to the exchange rate depreciation pressures observed in the currency market in case of higher values, whereas in case of lower or negative values, they denote appreciation pressures in the currency market. In pursuit of building early warning systems one needs to clearly distinguish the crisis and tranquil periods. To tackle this task, one needs to set such thresholds for indices so that the time periods corresponding to the index values above these thresholds are considered as crisis episodes. For the second group of indices (Versions 4, 5, 6, 7), the index value of 5 was chosen to be a threshold[21]. It should be noted that no single approach is available in the literature on the first group of indices, so the thresholds are usually chosen in such a way so that they best fit the objectives of any particular analysis[22], or that 5% of observations are crisis episodes[23]. A widespread approach is the usage of so-called "standard deviation" rules, which means that crisis episodes are the periods within which the index outstrips its average by some standard deviation. *Appendix 1* and *Appendix 2* show that the options 1.5, 2.0, 2.5 of standard deviation rules are the most common ones but the interval is quite broad and includes a great diversity of values from the range of {1.1, 3.0}.

Assuming that the distribution of EMP index calculated for Armenia is close to the normal distribution and under the probabilistic assumption of 5% probability of currency crises, the threshold value has been calculated using the 1.645 standard deviation rule for all three versions, as follows:

A crisis, if:

$$EMP > \mu + 1.645 * \sigma_{EMP}$$

where: μ is average and σ_{EMP} is standard deviation of the index.

Appendix 3 sums up the results of the above-referred 7 versions of EMP indices. Under almost all versions, currency crises[24] contemplated for Armenia are mainly distributed in the time interval 1997-2000, with an exception of a few values. Moreover, all versions of the index reported similar results, therefore, for the sake of simplicity, comprehensiveness, coherence and commonality in literature, we decided on *Version 1* as a Crisis Index chosen for further analysis.

Since the main results of the works for building early warning systems will depend on the choice and use of the index designed to distinguish crisis episodes, let us look at the main deficiencies our EMP index has:

- The weights of elements in the index depend on the movement of variables; this means that given abrupt volatilities in the series (potentially crisis-prone dynamics and, especially, dynamics in the opposite direction), the weights calculated based on standard deviation get smaller, so lots of potential crisis points could be missed, as a result. Some authors, disapproving such an approach to the weights of elements in the index, make a point that theoretically correct weights must be the estimated elasticity of reserves and interest rates to the change of exchange rate[25].

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[20] The absolute thresholds applied could be provided.
[21] Exploring the analysis regarding the Asian currency crisis, provided in the paper by Hawkins and Klau (2000), one may notice that the index has been mainly above 5 in crisis-hit countries, that is why that particular threshold was chosen.
[22] Abiad (2003), p. 3.
[23] Knedlik, Scheufele (2007), p. 13.
[24] Since actual currency crises (in accordance with the above definitions) have not been registered in the Republic of Armenia in the period under review, these values therefore should be considered as periods of possible crisis or profound depreciation pressures on the exchange rate.
[25] Li, Rajan, Willet (2006), p. 9.

- Determination of crisis thresholds also depends on the parameters of index dynamics (mean and standard deviation), so many potential crisis episodes often observable in the beginning of the series may pass unnoticeable due to crisis occurred in future, that is future developments have an impact on the results of past events.
- Many authors argue that some valuable information contained in the relevant index is lost when converting the continuous EMP index to a series with dual (0/1) variables[26]. That information may specifically relate to the intensity of the crisis or pressures.
- The most important is the rule of choice of the threshold level of the index, which is made at the discretion of the author and does not have a clear rationale.

Currency crises determinants

The stability of foreign exchange rate is usually of greater importance to developing rather than developed countries, since the latter have broader possibilities to affect their terms of trade, whereas the developing countries are largely reliant on the developments in the global market, being involved primarily in the exporting of raw material. Therefore, they increasingly attach greater importance to maintaining exchange rate stability as a tool for anchoring domestic inflationary expectations. Perhaps this is why a fixed exchange rate is an acceptable monetary regime for developing countries, which is possible to combine with only one of the objectives of domestic monetary independence or liberalization of capital flows, according to the rule of the "impossible trinity". However, very often in these countries, policy authorities attempt to accomplish the three objectives altogether, for the realization of some ambitious programs or because of existing financial problems. This may bring about currency crises, as a result. Although some of the above mentioned theories on crises only attribute a limited role to the main macroeconomic variables, it is however evident that the pre-crisis economic developments in developing countries are the main reason for the emergence of currency crises. Therefore, the relative popularity of the fixed exchange rate regime as well as inadequate economic developments provides room for an argument that currency crises are primarily inherent to developing countries. So, in order for crisis variables to be chosen, one must consider the causes for the currency collapses in these countries along with the discussion of the respective theories.

August of 1982 is considered the beginning of the 1980s crisis in Latin America, when Mexico declared about its depleted international reserves and incapacity to meet its own debt obligations. This is why that crisis was called a "debt crisis". A number of countries in Latin America came next to Mexico, crisis events began to be noticeable in the socialist countries of Eastern Europe (Poland) and in Africa as well, thus having involved a total of more than 40 countries[27]. On the brink of the crisis, the countries in Latin America were suffering budget imbalances, which were mainly financed by exceptionally expansionary monetary policies. However, this was not the only characteristic: external shocks also had a significant role. Specifically, the crisis was mainly determined by tight monetary policies implemented in advanced countries in response to the inflationary pressures observable in early 1980s, which came after an unprecedented buoyance of international credit made to the developing world with low interest rates. Foreign currency inflows to developing countries considerably declined, driven by economic deterioration in developed countries, a sharp drop in prices in international commodity markets and further reduction in the volume of foreign lending. This went in parallel with the deteriorating terms of trade and reduced export proceeds. Under financial liberalization and poor banking supervision Latin American countries were getting increasingly prone to the crisis. The tremendous capital inflows in 1970s were coupled with unprecedented volumes of credit expansion, thriving assets and real estate markets and increasingly stronger consumption. The rise in interest rates globally triggered a phase of capital outflows whilst contributing to an increased volume of non-performing loans, asset and real estate prices falls, and banking system instability problems. With mostly dollar-denominated bank deposits, a persisting dollarization contributed greatly to the economic downturn, as well. Moreover, the dollar credit disbursed from abroad was mainly used to on-lend in local currencies in domestic real estate markets. As a result of this, currency depreciation (devaluation) led to balance sheet problems in the banking sector, bank insolvency, sharp asset price falls, and another round of the vicious circle of depreciations.

[26] *Abiad (2003), p. 4.*
[27] *Krugman, Obstfeld (2000), p. 697.*

Though some theories undermine the role fundamentals played in the Mexican currency crisis in 1994 this was also attributable to some economic imbalances. Back in early 1990s, stepping modestly into the path to exchange rate liberalization, Mexican authorities have nevertheless kept the exchange rate near the ceiling of appreciation which led to real appreciation and creation of a large current account deficit. International reserves fell sharply: the liberalization of the capital account, which was done without adequate tools for regulation of the banking system contributed to this. Authorities' decision to allow a 15% devaluation of the exchange rate triggered a wave of speculative attacks, which led to the outbreak of the currency crisis.

Economic instability on the verge of financial crisis was typical not only to the Latin American crisis of the 1980s. The Asian crisis of the 1997-1998 unfolded through almost the same scenario although some analytics were considering it unique by its nature, attributing the origination of this crisis to sudden change in expectations and confidence and the spread of it to the effect of contagion. However, without detriment to any opinion, it should be noted that although economic, political and structural problems were underlying this crisis, peoples' expectations, the herd behavior and the contagion played a large part in its spreading and intensity. Unlike the Latin American crisis, the Asian crisis did not come after budget imbalances or worldwide rise in interest rates. Nevertheless, external shocks, namely adverse developments with the exchange rates of the main currencies, contributed to the emergence of the crisis. Back in the mid-1990s, the sharp appreciation of the U.S. dollar against the Japanese yen in the Asian countries whose currencies were pegged to the U.S. dollar (in the meantime Japan was their main trading partner), led to a loss of competitiveness. With tight monetary policy implementation in Japan in 1997, there was a threat of funds outflow initiated by the banks of the main lender in the region, virtually re-playing the crisis scenario of the 1980s. With all this, however, instability in the financial system, which came just after the expansion of domestic credit and soaring of assets and real estate prices owing to influx of international loan capital, was the main similarity between the two crises. The Asian countries' financial systems were more advanced, however: the economy monetization ratio was very strong, and the firms' debt was 2-3 times[28] the size of their assets. It was obvious that the economy mainly built on short-term foreign liabilities would have to be sensitive enough to any even negligible external shocks. In the context of the Asian crisis, such factors as political situation, legal framework, banking supervision and regulation and other structural variables turned out to be important as well.

Without reference to a number of other crises which came in emerging countries afterwards (Russia in 1998, Brazil in 1999, Argentina in 2001, Turkey in 2001), one may draw some major conclusions based on the developments reported with regard to the main currency crises. The choice of the right exchange rate regime, the monetary policy strategy, the raising of credibility of the central bank, the banking system supervision, the correct sequence of economic reforms, and the ability to understand the effects of contagion are very important considerations.

In the context of building EWS, for the purpose of the choice of leading indicators that signal currency crises, one would need, apart from learning the above theories and countries' experience, to observe the role of any particular variable in crisis prediction in different analytical papers. This problem was first systemically addressed in the paper by Kaminsky, Lizondo and Reinhart (1998)[29]. The authors have reviewed 105 leading indicators in 28 research papers regarding different aspects of currency crises and opted out a few of them which were of greater importance in most of the papers (see Appendix 4). Hawkins and Klau (2000)[30] and Abiad (2003)[31] have also reviewed the results of many research papers published in later periods, in 1998-2000 and 1999-2003, respectively, which is summed up in Appendix 4, too. We have also examined numerous research papers published in the period 1995-2008 in which predictive properties of variables were evaluated and which were not provided in the above-said three papers. The findings of these papers are also provided in Appendix 2 and Appendix 4. Summing up the findings in a total of 86 works we have chosen leading indicators signaling currency crises, which were relevant in at least 5 research papers (see Appendix 4), as follows:

- ✓ ***Overvaluation of real exchange rate:*** the real exchange rate is the most popular and practical variable; it is viewed in more than 65% of the works. An overvalued exchange rate has an opposite impact on exports, economic growth and external competitiveness of the economy. Leading to external instability and the loss of competitiveness, it can be viewed as the least level of potential depreciation.

[28] *Corsetti, Pesenti, Roubini (1998), p. 34.*
[29] *Kaminsky, Lizondo, Reinhart (1998), pp. 25-35.*
[30] *Hawkins, Klau (2000), pp. 3-5.*
[31] *Abiad (2003), pp. 46-53.*

- ✓ ***International reserves:*** the decline in the level of reserves points to the existence of problems the country has in external sector as well as to possible depreciation pressures on the exchange rate. In the meantime, a low level of reserves diminishes the central bank's ability to safeguard the local currency from speculative attacks.
- ✓ ***M2/International reserves:*** this variable is viewed as another indicator of a country's international reserves availability. M2 is considered the most probable broad money that can convert into a more stable currency. Therefore, this indicator denotes the central bank's ability to withstand exchange rate pressures determined by successive currency conversions.
- ✓ ***Domestic credit growth:*** credit growth is normally observed before the currency crises. This is true in consideration of the countries' experience as well as first-generation theories. The domestic credit growth usually follows the liberalization of the financial system and capital flows, which may result in problems associated with repayment of bank loans and mismatches in foreign exchange positions.
- ✓ ***Current account:*** the increase of the deficit of current account in GDP gives rise to serious concern in terms of foreign exchange receipts, heightening the likelihood of crisis. For Armenia, observing the current account is of greater importance as it is related to the issue of remittances (although the latter is treated as a separate variable), which provides the bulk of the country's foreign exchange receipts.
- ✓ ***Export growth rate:*** reduced exports will limit the country's capacity to obtain foreign currency, which may increase the likelihood of crisis. This indicator is another important factor that measures the loss of competitiveness as well as the problems existing with domestic firms. Besides, the low or negative export growth rate may serve basis to presume that the central bank would resort to the exchange rate depreciation in order to shore up exports and tackle current account-related problems.
- ✓ ***Real GDP growth rate:*** an economic decline is normally observable before the currency crises. In general, the country is more prone to crises when an adequate economic growth is not followed. This factor, however, is more important in the context of the country's dual objective function in the second-generation theories.
- ✓ ***Budget deficit:*** this is a classical indicator that describes currency crises as offered by Krugman. Persisting increment in the budget deficit points to an unsustainable government policy. It is usually financed owing to two principal sources: monetization of domestic debt and reduction in international reserves, each of which contains the main seeds of currency crises.
- ✓ ***Inflation:*** Though this indicator is rarely observed in the main theories, its role is important in assessing the country's overall macroeconomic environment. Moreover, it goes hand in hand with the high level of interest rates, which may create problems in the banking sector. It comes as no surprise that the importance of the indicator is underscored in about 20% of works on EWS studied.
- ✓ ***Short-term foreign debt:*** a massive influx of foreign capital follows the financial liberalization; this can be a cause of macroeconomic instability if we are talking exclusively about short-term debt-creating flows. The ratio of foreign debt to international reserves is another indicator that measures how much the country is secured with reserves. There is the Greenspan-Guidotti rule in economics stating that a country's reserves should at least equal the short-term foreign debt.
- ✓ ***Change in asset prices:*** bubbles in securities markets or such other asset markets often burst prior to currency crises. In addition, the falling of asset prices may witness the jeopardy of economic slowdown and loss of confidence. The indicator of securities price is usually discussed in various research papers but the real estate prices instead are also possible to consider.

Albeit the most commonly used variables (in 15% and more papers) were presented above, the choice is not limited to that, so nearly 24 leading indicators were chosen to lay under the further study in the paper (see Data Appendix, Table *DA* -3). Considering the argument of some authors that the structural and institutional variables play an important role in explaining the currency crises[32], and that CART methodology applied in our analysis allows evaluating their significance, we have included 3 structural variables – democracy of the political system, the election results and the selected foreign exchange rate regime, although the latter can be considered as classical indicators of currency crises (Fischer's two-polar approach[33]). The selected variables were used in different forms (absolute, relative, growth), which we will refer to in the next part of the study.

[32] *Ghosh, Ghosh (2002), p. 5, 23.*
[33] *Fischer (2001).*

Practical models for building early warning systems

By mid 1990s of the previous century, there has been plenty of theoretical and practical research to explain the various crises observed historically or to check the validity of the theory in question. Only after the so-called "tequila" crisis in Mexico in 1994-1995 researchers began focusing on the development of functional methods for prediction of currency crises. The Asian crisis in 1997-1998 paved a way for heightened motivation to launch work in this direction. The crisis urged many governments and private sector firms to build mechanisms that would be designed to monitor on an ongoing basis the countries' vulnerability to crises. Currently, in addition to the mechanisms applied by the international Monetary Fund (KLR, DCSD, PDR), similar models were designed and used by private firms, such as GS-Watch by Goldman Sachs, CSFB by Credit Suisse, Alarm Clock by Deutsche Bank, and etc. It is noteworthy that almost all of these mechanisms are used for prediction of crises in developing countries.

Various models are used to predict currency crises, and the most common of them (see Appendix 2) are probit/logit econometric models and Signals Approach modeling technique (this is often called Indicator Approach). The first works regarding the prediction of crises were authored by Eichengreen, Rose and Wyplosz (1995, 1996). These works contain graphically illustrated qualitative comparison of the movement of explanatory indicators in pre-crisis and post-crisis periods (often in crisis-prone and peaceful countries). Although this approach was the first of its kind and later was used by a number of other authors[34], it did not however gain much popularity. The two of the approaches introduced later – the probit/logit models and the Signals approach – grew into traditional models and started to be used almost in all early warning systems.

The most practical among them are the **probit/logit models** with dual choice. The first applications of the models are also associated with Eichengreen, Rose Wyplosz (1995, 1996). These models use the classical econometrical assessment techniques, by linking the probability of the crisis to the vector of explanatory variables. It gauges the extent of marginal contribution of each variable in explaining and predicting the crises. The main advantage is that they use a continuous series of explanatory variables, consider their possible multicolinearity and the ability to assess the statistical significance of each variable. The disadvantages are the possibility of using only a limited number of explanatory variables, necessity of certain statistical properties of the variables, the impossibility of addressing the issue of intersection between factors, and etc.

The Signaling approach is one of the non-parametric analytical methods developed by Kaminsky, Lizondo and Reinhart (1998). This is a simplest method based on the data on explanatory variables, which ignores the theoretical explanation underlying one or another variable or the existence of a structural model. Because more information on the Signaling approach will come later in this paper, let us just say that the main feature of this approach is that as opposed to probit/logit models it has a capacity to evaluate the possibility of false signals from different indicators and to measure their predicting power.

In addition to traditional methods, there are more than a dozen other models for building EWS, to the most prominent of which we will refer below[35]:

The Markov-Switching Models began to be used for explanation of the crises starting from 1998-1999. Because the crises are often determined through the use of multiple equilibria models the Markov's switching models have come to explain and predict economic switches between these points of equilibria. Whereas constant switching probability variants of the models were used initially like Jeanne, Masson (1998), Fratzscher (1999)[36], however at a later point the switching probabilities began to be observed as a function of various explanatory variables. The main advantage of using Markov switching models is that they are free of the need for initial definition and separation of currency crisis episodes (based on EMP index or otherwise), and crisis situations are identified and characterized endogenously as an output variable generated from model predictions. The main disadvantages of the model include the application complexity associated with their lack of standard econometrical software packages and the lack of various tests on statistical properties. However, in some cases, these models provide very good results compared with traditional approaches[37].

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[34] For example, Milesi-Ferretti, Razin (2000). A similar approach will also be used in the next section of this paper.
[35] For the review of almost all the main models known in the literature of EWS see Abiad (2003).
[36] Abiad (2003), p. 5.
[37] Knedlik, Scheufele (2007), p. 25; Abiad (2003), p. 44.

Artificial Neural Networks is a multi-dimensional, non-linear, non-parametric statistical method built on the analogy of human perception and neural system. Likewise, it contains sets of elements which are independent of each other but interact simultaneously; it represents a network that is equipped with properties intrinsic to human cognition, i.e. parallelism, connectionism, adaptability, self-organization. Artificial neural networks began applicable in the late 1980s as a solution to the problem of prognosis in various fields of economics (exchange rates, inflation, GDP, etc.). Currency crises by this approach were first addressed in the paper by Nag and Mitra (1999) in which their forecasting properties have outstripped the Signaling approach[38]. Multilayer neural networks also benefit when they are compared with another traditional approach, i.e. the probit / logit models[39]. In general, neural networks are characterized by a number of properties that make them valuable in solving such problems as approximation, cognition, classifications and forecasting. First, the results of these models are independent of the nature of the distribution of the variables. Second, neural networks are applied to the problems of economics, in which the linkage between variables has not been identified theoretically or is impossible to figure out how and when such interrelationships are non-linear. Third, this model is flexible, which allows for excellent results in terms of explanation (overfit), but which is a big disadvantage in terms of forecasting, however. The main disadvantage of neural networks is in their so-called "black box" nature: because there are no clearly estimated coefficients, it is impossible to identify the role and significance of individual variables in the projection. Finally, in view of prediction of currency crises and construction of EWS, artificial neural networks are implied to be complimented other models (mostly traditional ones) as they are not able to identify the key variables that determine the occurrence of crises, but only can provide for excellent forecast by the use of given indicators.

Classification Trees or ***Recursive Trees*** are a methodology which had been of a very little use in the EWS-related literature in spite of a bunch of most important advantages that are particularly related to the joint effects or intersection of variables and the possibility to study the role of various qualitative factors (details of this method are provided in the respective section of this paper). The reason of nonpopularity, perhaps, lies in the computational complexity of the method and a lack of relevant software provision, as well as the need for a large database.

We know a total of 3 studies that explore the currency and capital account crises by the use of this method. The first is the paper by Gosh and Gosh (2002)[40], which addresses the role of qualitative (categorical) variables that explain currency crises (features of the political system), considering their possible interactions. This study is the only one that covers EWS, as the paper by Kaminsky (2003)[41] attempts to figure out the nature of currency crises by the use of regression trees, while the other work by Chamon, Manasse, Prati (2007)[42] relates to the capital account crises, although this paper is more steered to the problem of forecasting.

Obviously, none of the models above-mentioned as well as the ones not considered here can provide excellent qualitative properties as they have a number of drawbacks even though each of them is designed to deal with selected problems. This is why at least two models are often used in the literature on EWS. Our paper will also deal with two models, i.e. the Signaling Approach and the Classification Trees[43].

CHAPTER 3

Early Warning Systems in Armenia

Early warning systems are designed to solve problems related to predicting crises in the monetary and banking systems or financial crises on the whole. These are efficient models which, once estimated on a basis of the situations already explored, can provide a disclosure of the set of leading indicators and their signaling mechanism. This paper is done in pursuit of building vibrant mechanisms for Armenia for its ability to predict currency crises. In this paper we attempted to explore two main approaches – the

[38] *Nag, Mitra (1999), p. 25.*
[39] *Peltonen (2006), p. 5.*
[40] *Ghosh and Ghosh (2002).*
[41] *Kaminsky (2003).*
[42] *Chamon, Manasse, Prati (2007).*
[43] *In future, we intend to also refer to probit/logit models, Markov Switching Model as well as Artificial Neural Networks*

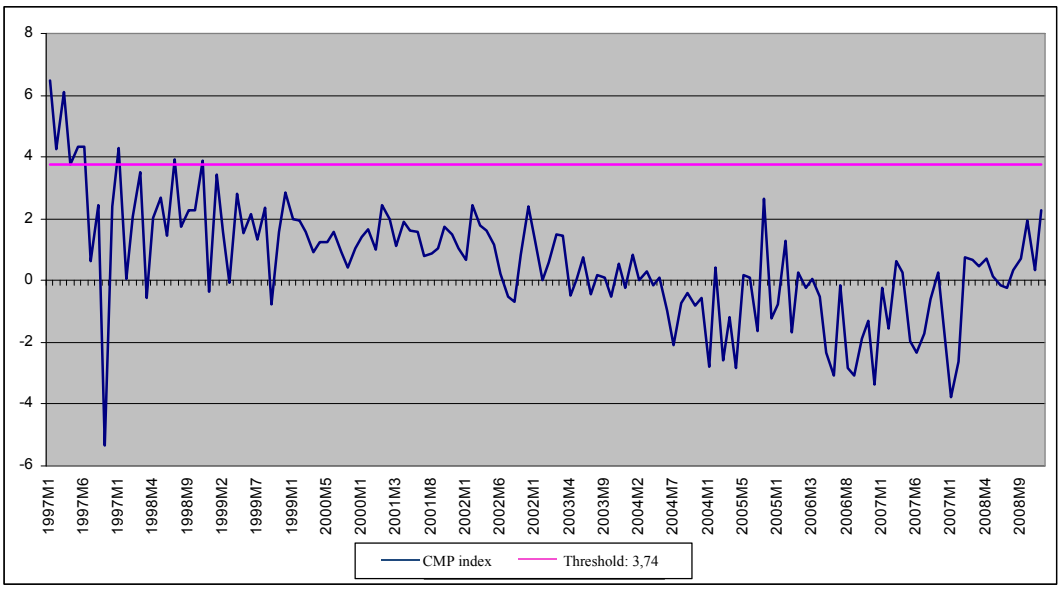
conventional Signaling Approach and the Classification and Regression Trees (CART) Method as a relatively new method which through its own specific algorithm best solves many problems associated with EWS (see the relevant section of the paper). We have also observed a number of EWS options and carried out various analytics (see Appendix 5 for general EWS structure developed for Armenia).

Distinguishing currency crisis episodes is key to understanding how EWS are to be established. In the context of the preliminary analysis of Armenia Exchange Market Pressures Index, the first version of EMP Index was accepted as the main crisis definition tool. Reviewing the results of many studies as well as additional analysis on Armenia, the threshold value for crisis index has been chosen using the 1.645 Standard Deviation Rule. It should be noted that in the construction of the models according to the CART methodology there were also used alternative options to EMP indices construction and crisis threshold calculations that is proposed below, which are called to resolve problems typical to crisis indices.

While discussing the approaches to currency crisis definition, it was noted that one of the main weaknesses of the proposed EMP index was the application of the entire series in building the components of the index and defining crisis threshold values, which could lead to some problems. We think crisis situations or currency pressures are more severe in relatively unstable periods of time but mitigate in periods of sustainable development. Therefore, the pressure of some intensity observable in relatively a stable period of time could bring in considerable crisis developments in that specific period whereas currency pressures with the same intensity might be interpreted as another innocent situation and failed to be characterized as crisis-relevant in an more unstable phase of economic development. Based on the aforementioned, we propose to apply two alternative options for definition of the crisis, on the basis of EMP index: according to the first approach the standard deviations and averages for both the index components (exchange rate, reserves, interest rates) in the phase of building a EMP index and the ultimate index in the phase of determining the crisis threshold[44] were constructed by the principle of moving window, with its length to have been defined 2 years[45] (the index and threshold level built for Armenia according to this option is presented in Figure 3-2). In the second option, the 2-year moving window was only applied for determination the crisis threshold only, meaning that though the index is built through the classic version, the crisis threshold is determined by the above-described principle of moving window, by adhering to the 1.645 Standard Deviation Rule (see Figure 3-3 for Armenia).

The comparison of traditional definition of currency crises (Figure 3-1) and two alternative indices for Armenia makes it obvious the problems we might encounter still in the initial phase of construction of EWS.

Figure 3-1: Traditional EMP index version (case of Armenia)



[44] *This is to assume that although the 1.645 SD Rule maintained the crisis threshold is subject to the principle of moving window and can vary at different time intervals,.*
[45] *This approach is partially close to the proposal by Zhang (2001) (source: Abiad (2003) (see Appendix 1).*

Figure 3-2: First alternative approach to EMP index (case of Armenia)

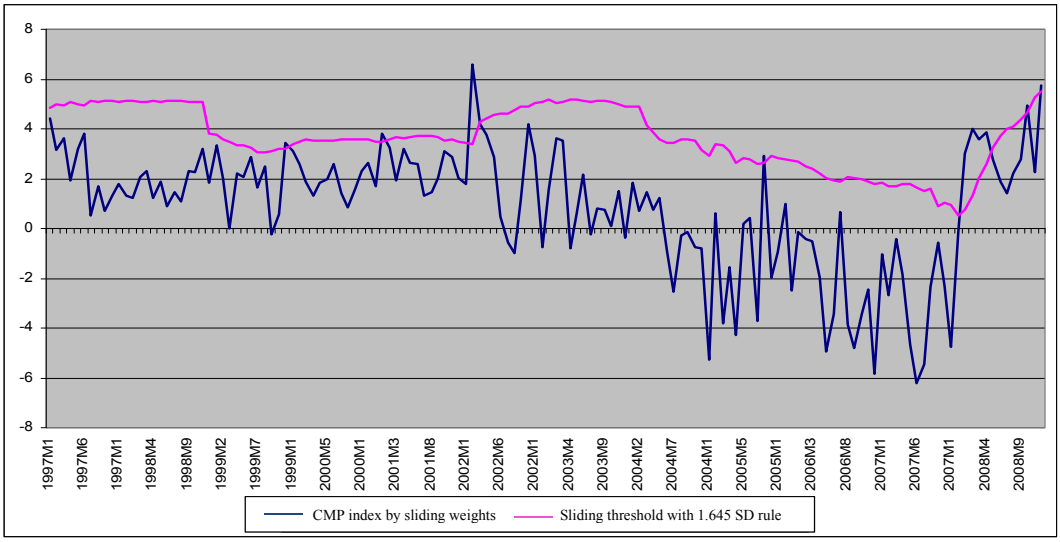
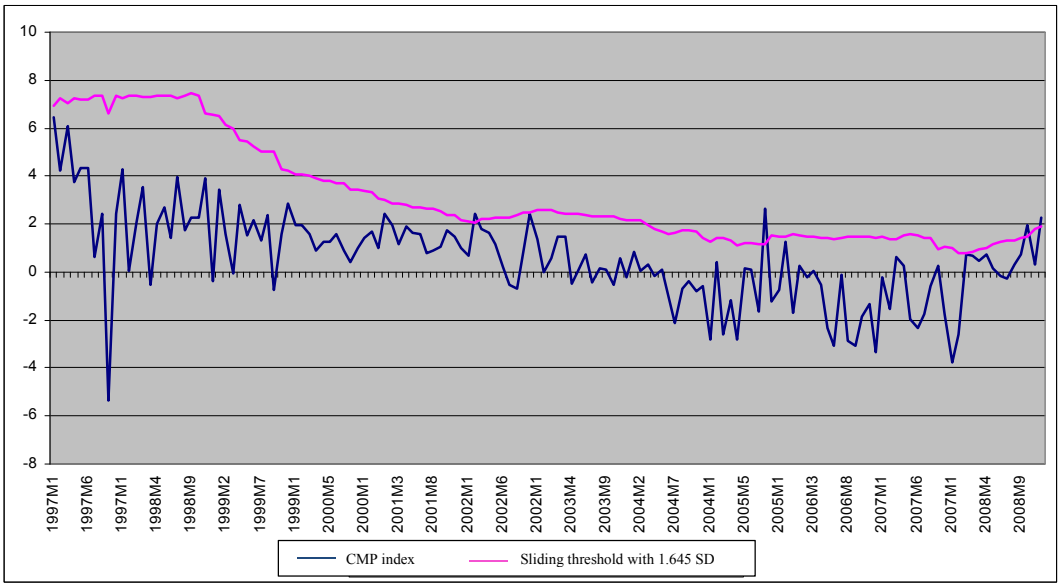


Figure 3-3: Second alternative approach to EMP index (Case of Armenia)



EWS predictive properties are largely determined by the ***choice of signaling horizon***. The signaling horizon is the time interval within which different leading indicators are believed to issue different signals about an upcoming crisis. After the review of numerous research papers and the studies of country experience (National Bank of Poland) as well as in consideration of the short-termness of time series, we have decided on a signaling horizon to be a 12-month window (or 4 quarters, in quarterly models).

Data compilation and preparation

The process of currency crisis analysis and construction of early warning systems in this paper was done by basing upon two groups of databases – the panel data and Armenia-relevant data. The panel option incorporates countries of Central and Eastern Europe and CIS, with a total of 21 countries, including the Republic of Armenia. The use of the panel option was suitable in a sense that the short-termness of statistical series pertaining to Armenia as well as the scarcity of crises taken place in the period under discussion did not give us an opportunity to build stable and convincing models. The

choice of the panel is determined by the need to explore the specificities of the region in the first place and the consideration of making useful conclusions about Armenia. However, since most data on the countries observed was not possible to obtain on a monthly basis, which is vital in terms of building an efficient EWS, the models were also built by only using monthly data on Armenia. It should be noted that the Signaling Approach below has considered the monthly data on Armenia only.

The database covers the monthly and quarterly series for the countries under discussion for the period 1990-2009. The length of time series for individual countries was determined as per availability of data (see Data Appendix, Tables DA-4, DA-5).

Most data rely on such main sources as the IMF International Financial Statistics database and the data provided from central banks and statistics services of the respective countries, and publications of various international organizations (see details in Data Appendix, Table DA-1).

The data undergo some preprocessing (individual sets of annual and quarterly data converted into quarterly and monthly data, respectively, seasonal adjustments if needed, etc.), to get the set of leading indicators which were then used in the subsequent analysis (description of data and specifics of respective adjustments is detailed in Data Appendix, Table DA-2).

Preliminary analysis of leading indicators

After we have defined the main EWS parameters, and before going to the construction of prediction models, let us first analyze the movement of the variables in the pre-crisis and post-crisis periods, based on both the panel and Armenia-relevant data. The graphical analysis in Appendix 6, which depicts the performance of individual variables within the signaling horizon and in aftermath the crisis in developing countries and Armenia, makes it clear that there are a number of interesting features to be discussed. One of the most important observations is that the deposits dollarization indicator for both panel and Armenia-relevant data trends up on the very eve of the crisis and afterwards. This is because of the "original sin" problem and the lack of confidence in the local currency in developing countries. Next important conclusion is about the behavior of real exchange rate as it goes abruptly an overvaluation path at least one quarter prior to the crisis and traces undervaluation immediately thereafter. The latter is a consequence of so-called overshooting. The difference of performance of indicators for the set of developing countries and Armenia is pronounced for *terms of trade* indicator: whereas the indicator reports a theoretically reasonable decline in Armenia prior to currency crisis, the panel data show high growth rates instead, which points to the weakness of this variable as a leading indicator (as we'll see later, almost all panel models support this fact). Going short of analysis of other variables, let us just add that the charts illustrate theoretically explained dynamics of the selected leading variables, so they can be included in the further works of construction of EWS models.

Signaling Approach as a tool for Predicting Currency Crises in Armenia

The Signaling approach is a non-parametric analysis method developed by Kaminsky, Lizondo and Reinhart (1998)[46]. It gained popularity in the literature in studying the problems of building of early warning systems for prediction of currency and financial crises. This method boasts a great scope of applicability in predicting turning points in business cycles based on macroeconomic and financial indicators. The characteristic feature of the latter is that, unlike the methods of parametric analytics (logit, probit), it is able to assess the ability of various factors to issue wrong signals and the capacity to predict crises. In general, the basic principle of Signaling Approach is as follows: when an indicator exceeds a certain threshold value it has been ascribed to, it is a warning signal that there is probability or threat of crisis in the upcoming signaling horizon.

The Signaling Approach involves a series of sequential steps the initial phases of which are common in almost all practical models for building EWS. Accordingly, building a model by the Signaling Approach will involve as follows:

1. definition and evaluation of currency crisis,
2. determination of the set of probable explanatory or leading indicators,
3. compilation of appropriate time series and determination of the length of the series and data frequency,

[46] *Kaminsky, Lizondo, Reinhart (1998).*

4. decision on the crisis window or the signaling horizon; this is the period prior to the crisis when variables are expected to issue a warning signal,
5. calculation of individual threshold values for each variable, which would enable to separate the tranquil period from the crisis period,
6. evaluation of predictive properties of various indicators,
7. construction of a Composite Index and evaluation of conditional probabilities of emergence of crises[47].

Since the first 4 steps are general to all the EWS models and the ones we build as well, these were addressed in detail in the previous sections of this paper. Note only that the model by the Signaling Approach is being built based on *Armenian* monthly data only, which cover a period from January 1996 through March 2009. For leading indicators, a total of 20 indicators were chosen out of the above list *(see Data Appendix),* which are non-institutional (non-categorical) in their nature. All other parameters are analogous to the above general principles, with the crisis rule of 1.645 standard deviation and the signaling window of 12 months.

Signals and thresholds: within a signaling horizon, if the value of an indicator goes beyond a certain level, it means it has signaled about the probability of emergence of a crisis in the course of upcoming 12-months, and that marginal level is the *signaling threshold* of that indicator. The signal is good if the crisis occurs within the crisis window after the signal has been issued, and if otherwise, the signal is considered to be false or a noise. The threshold level of each indicator is chosen so that there is a balance between the risk of false signals and the risk of missing the crises (first and second type errors). This is achieved as the noise-to-signal ratio (false signals to good signals) seeks to the minimum (we'll refer to this problem later).

The selection of indicator thresholds is done in two stages:

- the thresholds are defined in relation to percentiles of the distribution of observations of the respective indicator, and
- a grid of reference percentiles is constructed and the threshold that minimizes the noise-to-signal ratio is chosen to be the best threshold. Depending on which direction the indicators are expected to give a signal (above the threshold values or the values below them is a concern), two edges of the grid of reference percentiles are considered (5%-45% or 55%-95% of distributions)[48].

In the models under Signaling Approach, where panel data are applied in the main, the choice of the indicator thresholds is as follows: observations of all countries with regard to any particular indicator are brought together (provided the task is not to explore the crises in one country, as is the case with us), then the noise-to-signal ratio is built for each value of the reference percentiles of distribution of the indicator. Finally, the best threshold is the one for which the noise-to-signal ratio is the minimum. Once the best indicator thresholds are chosen, the threshold in question shall apply to the series of distribution of an appropriate indicator for the particular country. This means whereas the relative threshold of an indicator is the same for all countries, the absolute threshold varies across countries. For instance, if the noise-to-signal ratio for the indicator of "export growth" takes its minimum at the 15% percentile of the distribution of the series, the absolute threshold for the same percentile level for Armenia may be -2%, and, for example, for Romania, -0.7%. Our model only includes data pertaining to Armenia, so the chosen relative threshold and absolute value pertinent thereto are unique in the entire model.

The forecasting properties of variables under the Signaling Approach are estimated by dint of a bunch of indicators, the most important of which is the noise-to-signal ratio. For calculation of the latter, Kaminsky and others (1998) suggest using the following matrix:

	Crisis	No Crisis or Tranquility
Signal was issued	A	B
No signal was issued	C	D

In the matrix, A is the number of months for which the indicator has issued good signals, B is the number of months for which the indicator has issued false signals, C is the number of months for which the indicator has issued no such signals that would have been treated as good, D is the number of months for which the indicator has issued no such signals that would have been treated as false. Obviously, the indicator's predictive power would be perfect, if B = 0 and C = 0.

[47] This stage is absent in the paper by Kaminsky, Lizondo and Reinhatrt (1998) and is an important addition provided by certain authors to the above 6 classical phases.
[48] In an alternative version of our models built by the use of Signaling Approach, which is presented in Appendix 7, the grid of percentiles in the range 10%-35% and 65%-90% is applied.

So, the noise-to-signal ratio is calculated as a ratio of actually reported false signals as a share of potentially false signals to actually reported good signals as a share of potentially good signals, or based on the matrix above:

$$NSR = \frac{B/B+D}{A/A+C}$$

This ratio allows not only figuring out the threshold values of indicators but also assessing ***predictive properties (performance)*** of each factor[49]. The indicator is considered to have predictive properties if its noise-to-signal ratio is considerably below 1. Usually, the variables with values above 1 of the noise-to-signal ratio are not considered in the prediction models.

For calculation of threshold values and the respective noise-to-signal ratios, one would need to analyze the leading indicators with respect to the EMP index movements (this is applied to reveal the crisis episodes), in order to disclose marginal thresholds that provide the minimum level of the noise-to-signal ratio. Therefore, in the context of crisis episodes revealed by the use of the chosen EMP index and a respective rule, we have evaluated predicting properties of the factors and the relevant thresholds, which is presented in Table 3-1. Note that the option of 5%-45% and 55%-95% grid of reference percentiles was used in the example provided[50].

As is shown in the table, such factors as inflation, credit/deposit ratio, foreign debt, money supply, and other indicators came in with the best performance. It is noteworthy that the best results in terms of both conditional probability and response to the crises were also attributable to the inflation indicator. Thus, if the y-o-y inflation exceeds the threshold value of 9.6%, all else being equal, currency pressures may become possible in the upcoming 12-month horizon with about 97% of probability. It should be noted that only such indicators as inflation and the banking system's assets-to-liabilities ratio have responded to all 10 crises observed in the reference period.

In general, almost all the variables addressed have shown strong predictive power: by 17 factors out of 20, the noise-to-signal ratio is below the value 0.5. Only short-term foreign debt and dollarization indicators posted a complete powerlessness (the noise-to-signal ratio is above 1). This provides good support to the best capabilities of selected variables. These indicators have provided the best results in many studies reviewed. Thus, all the variables (perhaps with the exception of short-term foreign debt/international reserves, dollarization, and, with some reservation, the budget deficit) can be considered as leading indicators for predicting currency crises in Armenia.

Table 3-1: Performance of leading indicators for predicting currency crises (Option 1)[51]

	Absolute threshold	Relative threshold (percentile)	Noise-to-signal ratio	Conditional probability* (%)	Crises signaled** (%)	Significance
	1	*2*	*3*	*4*	*5*	*6*
Export growth rate	-26.856	0.08	0.055	85.714	70	6
Real exchange rate overvaluation	4.772	0.94	0.253	54.545	90	14
M2/International reserves	110.663	0.94	0.041	90.909	10	4
Real estate price growth rate	-0.058	0.12	0.082	66.667	10	7
Current account/GDP	-19.940	0.13	0.108	73.684	90	9
Budget deficit/GDP	-2.986	0.07	0.810	27.273	30	18

[49] The choice of best thresholds of factors, which implies minimization of the noise-to-signal ratio, can also be interpreted in the context of statistical testing by introducing the idea of Type I and Type II errors. Let the emergence of a crisis be the zero hypothesis (H_O) and the lack of a crisis be an alternative hypothesis (H_A). According to the above matrix, we can see that H_O=A+C and H_A=B+D. The size of Type I error equals the probability of rejection of hypothesis H_O, while it is true: so, Pr(rejection of H_O / H_O is true), that is to say, Type I error is defined as C/(C+A). Type II error is accepting hypothesis H_O, when it is not true: so, Pr(accept H_O / H_O is wrong), that is, it can be defined as B/(B+D). Therefore, the best thresholds are chosen by striking a balance between Type I and Type II errors, which is carried out through the noise-to-signal ratio. So, the latter would be defined as a ratio of Type I error over 1 minus Type II error, that is (B/(B+D))/(1-C/(A+C)).

[50] The results of the alternative version, which uses the grid of percentiles in the range 10%-35% and 65%-90%, are presented in Appendix 7.

[51] Kaminsky, Lizondo, Reinhart (1998) use a lot of other statistics in their paper, which we did not include in this table but they could be provided, if needed.

	1	2	3	4	5	6
Short-term foreign debt/International reserves	28.641	0.56	6.384	5.797	10	19
Domestic credit growth rate	79.388	0.93	0.235	63.636	20	13
External debt/GDP	64.162	0.94	0.036	88.889	70	3
Inflation	9.566	0.8	0.013	96.774	100	1
Economic growth	4.056	0.15	0.301	57.692	90	15
Remittance growth rate	-27.667	0.05	0.118	62.500	20	10
Banks' foreign assets/foreign liabilities	46.285	0.22	0.096	81.081	100	8
Terms of trade	-2.027	0.13	0.442	40	40	17
Credit/Deposits	193.612	0.86	0.020	95.455	90	2
International oil prices	20.140	0.25	0.183	69.231	90	12
Difference of long-term and short-term interest rates	26.612	0.94	0.046	90	90	5
World economic growth	-4.707	0.05	0.411	50	10	16
Dollarization	70.054	0.55	13.964	2.857	20	20
International reserves/GDP	13.219	0.08	0.169	64.286	10	11

** Probability that a crisis may emerge, provided that the indicator has issued a signal A/(A+B).*
*** Denotes that part of the crises that a particular indicator has called.*

At any given time interval, the more the indicators issue signals about a potential crisis, the higher the probability that it would happen. So, in order to assess a country's vulnerability to crises, we need to have all the signals in combination. To deal with the problem, Kaminsky (1998) has explored 4 versions of building a Composite Index in them the versions with simple sums of signals and taking into account the intensity of the signals and predictive properties of respective indicators, and arrived at a conclusion that the best results in terms of forecasting power for both banking and currency crises are attributable to that option of Composite Index which accounts for forecasting accuracy of individual indicators[52].

So, in our paper, we too will use the option of the Composite Index that combines all signaling indicators into a single ratio by taking account the prognostic qualities of indicators (the noise-to-signal ratio).

However, before ever attempting to build a Composite Index, Bruggemann and Linne (2002) are proposing to get the intensity of each indicator within the signaling window[53]. Furthermore, instead of simply computing the number of signals of the indicator, as is known in conventional wisdom, what they propose though is to weigh each of these signals by their relative position inside the window. That is, realizing that earlier signals are of less importance than the recent ones, the principle of moving average will be used here to build the indicators, as follows:

$$Z_t^j = \sum_{i=1}^{12} \frac{I_{t+1-i}^j}{i} \quad t \geq 12$$

where: j – is the respective number of an indicator, I – is the value of an indicator (0,1): 1, if the indicator has issued a signal about the potential crisis, 0, otherwise, i – is the position of the indicator in the 12-month window.

Once the calculation of these interim indicators is complete, the Composite Index will be built by weighing the specified values by noise-to-signal ratios of respective indicators:

$$CI_t = \sum_{j=1}^{k} \frac{Z_t^j}{NSR^j}$$

where: j – is the respective number of an indicator, k – is the number of indicators in review, NSR – is the noise-to-signal ratio.

Certainly, this type of Composite Index is important in consideration that the indicators equipped with best predictive qualities (indicators with the least noise-to-signal ratios) get the biggest weights.

Though the Composite Index can give an idea of the change in intensity of crisis-related signals delivered from the variables, its values cannot be interpreted nevertheless: perhaps the growth of the index may denote an relatively heightened likelihood of crisis and, vice versa, the lower values of the index would hint weakened pressures in the macroeconomic environment.

[52] *Kaminsky (1998), p. 16-18, 20.*
[53] *Bruggemann, Linne (2002), p.12.*

However, the values of Composite Index allow us determining the conditional probability of emergence of crises, depending on which interval the index has taken a value from. A probability like this is estimated as follows:

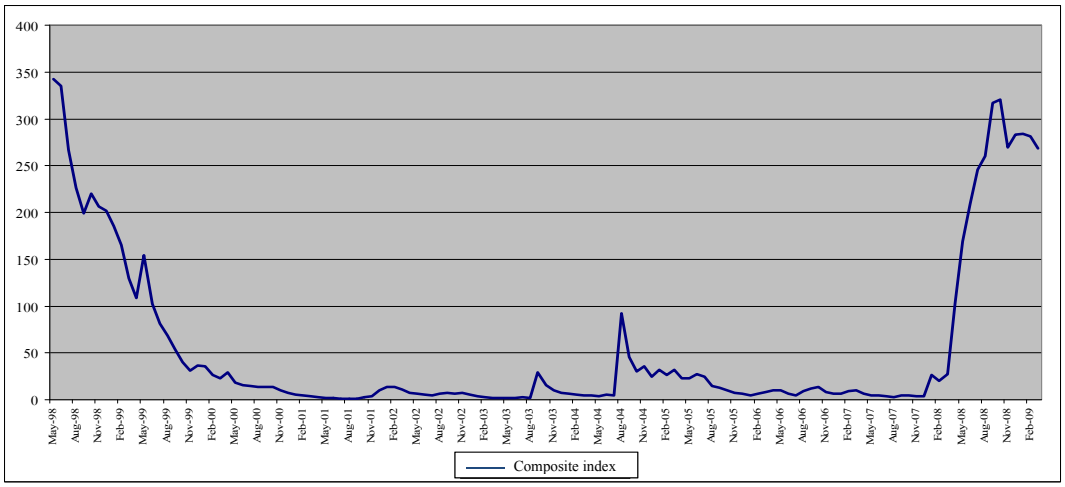
$$P(C_{t,t+24} \mid CI_u \le CI_t \le CI_v) = \frac{\sum monthCI_u \le CI_t \le CI_v \longrightarrow crisis}{\sum monthCI_u \le CI_t \le CI_v}$$

where: $C_{t,t+12}$ *- is probability of a crisis in the course of the 12 months following t,* CI_u *and* CI_v *- are conditional lower and upper bounds of the values of Composite Index. The numerator of the formula has the number of months for which the index has been within the selected range, and the crisis has occurred in the course of 12 months followed, and the denominator has the total number of months for which the index has been within the range.*

According to above methodology a Composite Index is built for the Armenian economy. The index comprises all 20 variables despite the fact that two of them – the short-term foreign debt and the dollarization – have a noise-to-signal ratio above 1. Normally, indicators with coefficients above 1 are not included in the models. However, because all the other variables have demonstrated a maximum noise-to-signal ratio of 0.5 (except the budget deficit of 0.81), while that ratio of the two noisy variables is way above 1, we may state the latter would not have a significant impact on the value of the index but could bring the effects of selected events into the model instead[54].

The dynamics of Composite Index *(see Figure 3-4)* shows that it has issued most of the signals by the year 2000 but performed fairly steadily in the period 2000-2007.

Figure 3-4: Composite Index dynamics



The Figure demonstrates several steep jumps of the index, which implies that the likelihood of a crisis in the upcoming 12 months was increasing. In particular, starting April 2008, the Composite Index has trended abruptly upward, which meant intensification of currency pressures by end-2008 and the beginning of 2009.

In order to produce a probabilistic summary estimation of the country's vulnerability to crises, we matched the dynamics of Composite Index with the EMP index movement and calculated the conditional probability of currency crises in the event the Composite Index takes values from different ranges. Since in total 10 episodes (including March of 2009) out of 147 po ssible were chosen out by the use of the EMP index to be crisis-hit, the unconditional probability of currency crises is 6.8%. Usually in literature, the index intervals for calculating the conditional probabilities are chosen arbitrarily. However, for the sake of more reasonable choice, we use CART methodology (see details in the next section) which has distinguished the appropriate ranges (see Table 3-2).

[54] *In Appendix 7, where an alternative network of percentiles was used in building Composite Indices, the factors with noise-to-signal ratios above 1 were excluded.*

Table 3-2: Conditional probabilities of the crisis by Composite Index value

Composite index	Conditional probability (%)
0-27.08	0
27.08-102.76	5.55
102.76-167.11	20
167.11 and over	91.43
Non-conditional probability	**6.8**

As shown in Table *3-2,* higher values of the index are associated with higher probability of crisis. Moreover, 32 values out of 35 values above 167.11 of Composite Index have predicted crises. The value 167.11 can be considered the threshold level of the index as, once above that level, the probability of emergence of the crisis exceeds 50%. Sure, the closing interval is anyhow possible to divide into sub-intervals so as to produce a more gradual hierarchy of probabilities but because a mechanism of cross-validations in CART enables to consider the model's general predictive properties in determining the thresholds, we find it reasonable to rely upon the CART results solely.

While the probabilities presented are quite promising, in the context of this methodology it is possible to forecast the probability of a crisis for the upcoming 12 months, i.e. the probability of emergence of the crisis any time in the 12-month window. Therefore, for building a Composite Index, we are proposing to use another indicator that would allow predicting the probability of the crisis as of any particular month. The coefficient is calculated, as follows:

$$Z_t^j = \sum_{i=1}^{12} \frac{I_{t+1-i}^j}{(13-i)}$$

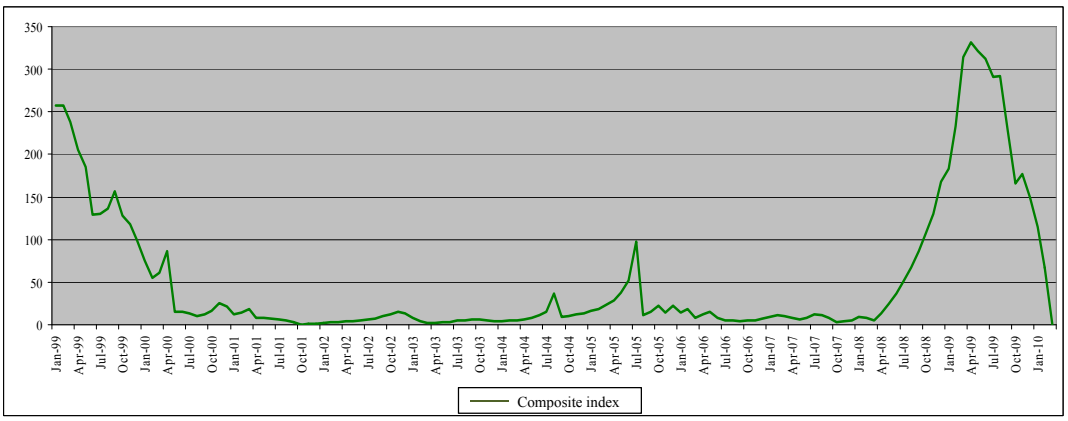
The implication of this coefficient is that the probability of emergence of the crisis at any given time depends on the signals various indicators had issued in the course of 12 months prior to that time. However, since any signal of the indicator is pertinent to the 12 months coming next, the highest weight will therefore be prescribed to the most distant signal and the lowest weight to the nearest signal, for any given time.

The next steps of calculating the Composite Index comply with the above description, with the only difference that the probability of the crisis is estimated as of any particular month:

$$P(C_t | CI_u \le CI_t \le CI_v) = \frac{\sum monthCI_u \le CI_t \le CI_v \longrightarrow crisis}{\sum monthCI_u \le CI_t \le CI_v}$$

The dynamics of the Composite Index calculated through this approach is presented in Figure *3-5,* which exhibits roughly the same trend patterns while predicts relative tranquility for the period 2001-2008.

Figure 3-5: Composite Index dynamics (instant approach)



The index also shows that starting from October of 2008 the value of the index has grown sharply and hit its ceiling in March-May of 2009. These developments demonstrate that the probability of emergence of the crisis reached the peak during those months, which materialized in March of 2009 in the form of sharp depreciation of the exchange rate. Interestingly, the index makes some amount of forecast for the upcoming months by basing upon data prior to March of 2009. Although these forecasts are subject to adjustment, they can confirm to the gradual weakening of overall macroeconomic tensions in the economy in the period up to the first half of 2010.

For this method, the probabilities were also assessed using the CART methodology, and are presented in Table 3-3.

Table 3-3: Conditional probabilities of the crisis by Composite Index value (instant approach)

Composite index	Conditional probability (%)
0 – 314.68	0
314.68-413.9	25
413.9 and over	75
Non-conditional probability	**6.8**

The distribution of probabilities in the table also pinpoints that high index values determine greater crisis likelihood: no value almost up to 315 of the index has been registered in any crisis observed. If the index value exceeds 413.9, the probability of the crisis reaches 75% (6 crises out of 9 observed have occurred in the incidence of these values). In the most recent March of 2009 depreciation of the exchange rate the index reported a value level of 315, which meant a 25% probabilistic situation.

Classification and Regression Trees in EWS

The Classification and Regression Trees (CART) approach is a binary statistical data classification algorithm which was developed in the mid-1980s by American Scientists[55]. It has applications in many areas: the first applications pertain to shipbuilding, predicting heart seizures; in finance and economics, it has been applicable back in 1985 for the classification of distressed firms by Friedman, Altman, and Kao and classification of commercial loans by Marais, Patel, and Wolfson. Recent applications include the disclosure of the nature of currency crises by Kaminsky (2003), the aspects of prediction and clarification of capital account crisis by Chamon, Manasse, Prati (2007). The only study we know more or less relating to the problems of EWS that uses this methodology is Gosh and Gosh's (2002) research.

CART is a statistical tool or technique for non-parametric analysis, which solves, in a broader sense, the problem of systematic representation of decision rules in the form of binary trees; in a narrower sense, it identifies the list and importance of the input variables that best describe and predict a specific outcome of a certain dependent variable. Moreover, the dependent variable can be either of discrete type (categorical), in which case the Classification tree is used, or continuous, in which case the Regression tree is used (the main principles of construction of Regression trees are presented in Appendix 9).

The main task of CART is to identify classifiers or respective prediction structures, which makes it possible to classify future observations into appropriate groups (for example, crisis or non-crisis, an average exchange rate appreciation of 5% or 2%, or depreciation of 4%, etc.).

CART classification mechanism bases on three main elements:

- the sample-splitting rule,
- the goodness-of-split criteria,
- the criteria for choosing an optimal or final tree.

In general, the construction of the tree through CART is carried in following steps:

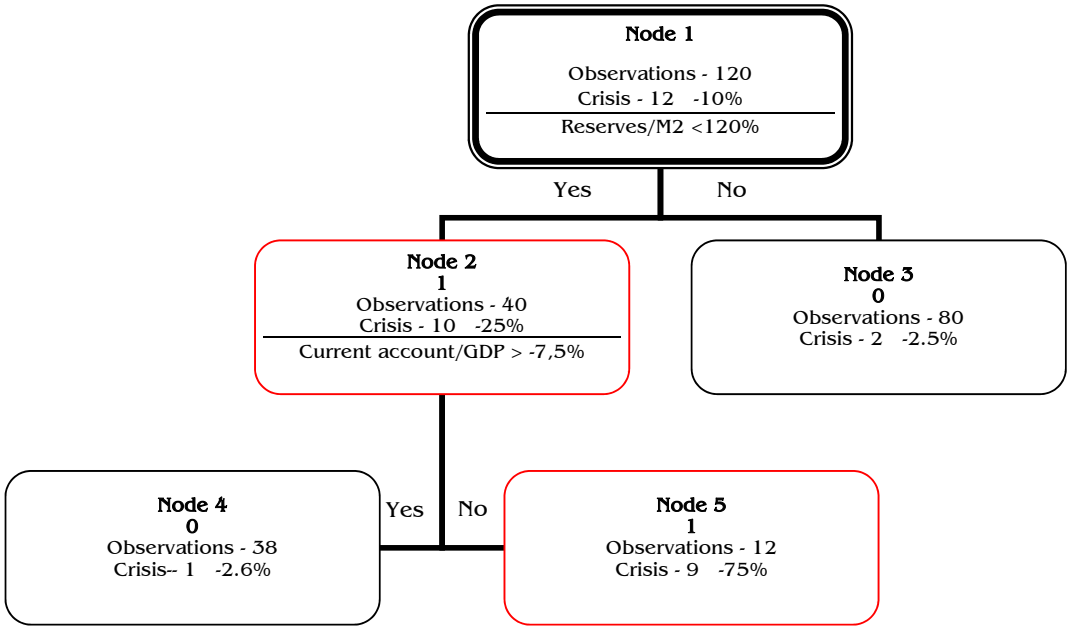
- initial split of observations into two sub-groups, right and left sub-groups, based on some simple question about an explanatory variable requiring 'Yes' or 'No' answers,
- the sub-groups, which are called nodes, are also divided in the manner above described. In these subsequent steps the biggest possible tree is built, and each *terminal node* (which no longer can be split) of the tree is characterized by absolute homogeneity of the observations included,

[55] *The theoretical and empirical aspects of this approach are provided in the book Bremen Leo, Friedman H. Jerome, et. al. "Classification and Regression Trees", The Wadsworth Statistics/Probability Series, 1984.*

- from the biggest possible tree, which best interprets the present observations yet falls short of the correct classification of new observations, the optimal or effective tree is pruned, which is the one that meets the chosen criterion (exemplary illustration in Figure 3-6).

In the process of construction of Classification Tree, assigning classes to the appropriate nodes (whether terminal or intermediate) is very important[56]. Although each tree node is described by the number of observations related to each value (class) of the discrete dependent variable, only one adequate class (usually with a bigger share) is assigned to the node. Assigning classes to the nodes is also important in terms of evaluation of predictive properties of the trees and the choice of the optimal trees.

Figure 3-6: An Example of a Classifications Tree for currency crisis



In the figure, Nodes 3, 4 and 5 are terminal nodes, while Node 2 is non-terminal. As such, each node has been assigned a respective class: 0 for non-crisis and 1 for crisis situations.

Classifications Tree Construction Methodology

Constructing a Classifications tree requires three basic elements. These are:

- a set of questions that underlie the split,
- splitting rules and goodness-of-split criteria,
- rules for assigning a class to each terminal node.

There are two formats of ***splitting questions*** applied in CART:

1. Is $X \leq d$, where X is a continuous variable, and d is any constant value out of the X series, e.g. whether *income* $\leq$ *$2000,*
2. Is $Z=b$, where Z is a categorical variable, and b is any discrete integer value taken by Z, e.g. whether *gender=1.*

Before ***splitting rules*** and ***goodness-of-split criteria*** are discussed, let us refer to the *impurity function* and *impurity measure,* which are vital in determining the splitting rules and goodness-of-split criteria.

Let $j=1, 2, \ldots\ldots, k$ are the numbers of possible classes assigned to the categorical dependent variable; in this case $P(j \mid t)$ will represent the class probability distribution of the dependent variable in node t, such that:

[56] *In regression trees, the class-assignment is not required, and statistical descriptors of nodes come to substitute them.*

$P(1 / t) + P(2 / t) + \ldots\ldots + P(k / t) = 1$

Thus, the impurity function[57] is defined as a function of the above-said class probabilities:

$i(t) = \Phi(P(1 / t), P(2 / t), \ldots\ldots, P(j / t))$

Moreover, the definition of impurity measure allows for flexibility of functional forms.

Splitting rules: there are many splitting rules applied in CART, and the most common of them are three – the Gini criterion, the twoing rule, and the linear combination splits. In addition to these main splitting rules, CART users can define a number of other rules for their own analytical needs.

The Gini criterion is the most common, so let us examine that in detail. The Gini impurity measure is defined as follows: $i(t) = 1 - S$, where: $S = \sum_{j=1}^{k} P^2(j \mid t)$. This impurity function takes its maximum value when the probabilities of all classes are equal in the node: $P(1 / t) = P(2 / t) = \ldots\ldots = P(k / t)$, and attains its minimum (=0) when all observations of the node belong to only one class.

Goodness-of-split criteria: let *s* be a split of *t* node into two sub-nodes. In this case, the goodness-of-split of the "*s*" is defined as reduction of the impurity measure:

$\Delta i(s,t) = i(t) - P_L(i(t_L)) - P_R(i(t_R))$

where: s is a particular split, P_L and P_R are those proportions of cases at node t that go to the left and right child nodes respectively, $i(t_L)$ and $i(t_R)$ are the impurities of the left and right nodes, respectively.

Class assignment rule: before discussing the basics for rules, let us turn to the idea of prior probabilities at first. There are three types of priors in CART – data priors, equal priors and mixed priors. These are to be estimated from the data or have to be inputted by the researcher (user).

Now, assume N is the number of observations in the sample, N_j is the number of cases belonging to the class j in the observations, π_j is the prior of the cases belonging to the class j.

- *Data prior* assumes that the class distribution of the dependent variable in the population is the same as in the sample $\pi_j = N_j / N$.
- *Equal prior* implies that the probabilities that all classes of the dependent variable would appear in the population are equal. For example, if the dependent variable in the sample is a categorical with two classes, then the probability of occurrence of each of them equals.
- *Mixed prior* is the average of the above two priors for each class.

Now, let us refer to the class assignment rules. Classes are assigned to all the nodes, including terminal, intermediate and even root nodes. There are two assignment rules, each of which is based on one type of the misclassification costs.

- *The Plurality rule:* assign terminal node t to a class for which the $P(j / t)$ is the biggest, that is, if majority of cases in the terminal node belong to a class, then the node is assigned to that class. In fact, this rule assumes equal misclassification costs for each class.
- Assign terminal node t to a class for which the expected *misclassification cost* is at a *minimum.* This rule takes into account the severity of wrong classification, so it inputs the variable cost into the Gini criterion.

For example, when discussing aspects of currency crises, wrong assignment of classes to the node is relatively a serious concern; in this context, wrong classification will mean, for example, assigning a period of tranquility to the crisis situation and vice versa. Therefore, this problem is tackled by building a misclassification costs matrix with elements as $c(i / j)$: this is the cost of classifying class *j* case as class *i* case:

$c(i / j) \geq 1$, »Γ» $i \neq j$ Ë $c(i / j) = 0$, »Γ» $i = j$

Taking into account the priors and misclassification costs, we will get the cost of assigning a class to the terminal node:

$$r_j(t) = \pi(j) \cdot \prod_{i=1}^{k} c(i \mid j), \; i \neq j$$

[57] *The impurity function is designed to measure the extent of homogeneity. In this context it can be considered as a variance or dispersion of observations in the node.*

Accordingly, if we assume that $r_1(t)<max(r_j(t), j=2, 3, ..., k)$, then Class 1 will be assigned to that particular terminal node, according to the Rule 2. If all $c(i / j)$ are equal, then Rule 1 (the Plurality rule) applies, and the node is assigned to a class for which prior probability is the highest. So, the class assignment will be as follows:

node t is assigned to class i, if:

$$\frac{C(j \mid i)\pi(i)N_i(t)}{C(i \mid j)\pi(j)N_j(t)} > \frac{N_i}{N_j} \text{ for all } j,$$

where: $N_i(t)$ is the number of observations of class i in node t, N_i is the number of observations of class i in the dataset.

In fact, this definition takes into account the costs associated with the decision on classification of future observations by basing upon the classification tree as well as prior probabilities of different classes.

Based on the main elements above, classification the construction of the tree will involve several stages, aiming to get more homogeneous nodes out of the root node that is strongly heterogeneous. Starting from the root node, the tree construction process includes:

1. The data set based on all possible values (data points) of all the variables is split into two binary sub-groups. Cases with a "yes" response to the question posed are sent to the left node and those with "no" responses are sent to the right node.
2. CART then applies its goodness-of-split criteria to each split point of each of the variables and evaluates the reduction in impurity. CART selects the best split of the best variable as that split for which the reduction in impurity is the highest.
3. CART then assigns classes to these nodes according to the rule that minimizes misclassification costs.
4. Because the CART procedure is recursive, steps 1–3 are repeatedly applied to each non terminal child node at each successive stage.
5. CART continues the splitting process until the largest possible tree is built. The terminal nodes of this largest tree are not susceptible to further split as they are either pure (absolutely homogeneous) or have very few (often one) cases.

Large trees which are called complex trees (the complexity of a tree is measured by the number of its terminal nodes), can have two types of problems: 1/ understanding and interpreting trees with a large number of terminal nodes is a complicated process, and 2/ although they are highly accurate, with low or zero misclassification rates, large trees provide poor results when applied to new data sets and new classification of observations. This is because the tree is fully aligned with the data observed, and is set to explain the impact of both the fundamentals and different noises. Because the noises are different by nature, the branches of the tree that explain such noises shall be separated or eliminated (pruned) so that the tree is able to make accurate forecasts. CART offers a solution to this problem by means of the Tree Pruning Algorithm. The pruning of the tree starts from the lowest branches and gradually prunes terminal nodes, provided that the new misclassification cost is smaller than the change of complexity of the tree. So, there appears a trade-off between complexity of the tree and its accuracy. The relationship between tree complexity and accuracy can be understood with the cost complexity measure, which is defined as follows:

Cost Complexity = Resubstitution Misclassification Cost + β * Number of terminal nodes,

The resubstitution misclassification cost is estimated only on the basis of observed data set that is why it is often called internal misclassification cost: the value of the latter declines gradually with the increase in the complexity of the tree, since larger trees better fit the data. Therefore, the misclassification cost of the largest possible tree attains zero. In fact, the latter is similar to R^2 measure of regression, which can be increased with the inclusion of more explanatory variables. However, as it was noted earlier, the increase in size of the tree leads to higher complexity costs in the form of increase in the number of terminal nodes.

CART has a built-in algorithm that estimates β parameter of complexity; the main sense is to achieve a balance between the cost-complexity coefficients of the two neighboring trees pruned, producing the marginal value of β. Refraining from presenting the complicated algorithm of complexity parameter calculation, let us only note that its value increases gradually with the reducing of complexity of the tree.

The pruning of the largest tree results in a series of sequentially nested subtrees from which an optimal tree with the best predictive properties is chosen.

A question may arise as to how the ***predictive properties of the trees*** are measured. Let us refer to a CART built-in method called K-fold cross-validation. The method implies that the observations for cross-validation and predictive accuracy assessment problems are chosen out of the existing datasets rather than from values expected. Thus, if we define:

- $C(X)$ as a tree-structure classifier of X vector of the characteristics variables that describe observations,
- $R(C(X))$ as the classifier's misclassification rate,
- L as the learning sample (the sample data from which to construct a classification tree),

then the process of K-fold cross-validation can be presented as sequence of the following steps:

1. L sample is split into K sub-samples with equal number of observations $L_1, L_2, \ldots\ldots\ldots L_K$;.
2. A classifier $C(X)$ is constructed from (K-1) subsamples by leaving out, say, the K subsample – L_K;.
3. The resulting $C(X)$ classifier is saved.
4. The saved classifier $C(X)$ is applied to the excluded cross-validation sub-sample L_K, and the misclassification rate $R(C^K(X))$ is estimated as a proportion of misclassified observations.
5. Steps 2-4 are repeated, using all subsamples except the subsample of L_{K-1} which now becomes a cross-validation test sample. The process above is repeated until every subsample is used at least once as a construction sample and once as a cross-validating test sample.
6. In the outcome, the real estimate of $R(C(X))$ is calculated as a simple mean of misclassification coefficients $R(C^K(X))$ $R(C^{K-1}(X))$ $R(C^{K-2}(X))$, …, $R(C^1(X))$, as follows:

$$R^{c-k}(C(X)) = 1/K \sum_{k=1} R(C^K(X))$$

It shall be noted that the choice of K is arbitrarily made by the researcher, however a widely accepted and spread value is K=10, that is 10-fold cross-validation.

Thus, the K-fold cross-validation method is applied to evaluate qualitative properties of and compare them between different trees of different size. In the closing stage of pruning, the best chosen tree is the one the cross-validation misclassification value of which is one standard deviation away from the minimum value of misclassification, and which has the minimum terminal nodes among the whole subsets of trees. The one standard deviation rule is controversial and can be changed by the researcher, but is a quite widespread rule.

The K-fold cross-validation method also allows determining out-of-sample predictive properties of the tree pruned.

Because applying CART methodology is not widespread in building EWS and this work is among the pioneers, we therefore find it reasonable to talk about strengths and weaknesses of the methodology while considering its use in EWS construction.

Strengths

1. CART makes no distributional assumptions of any kind for dependent and independent variables.
2. CART is a non-parametric method and does not assume specification of functional forms.
3. The explanatory variables in CART can be a mixture of quantitative (continuous) and qualitative (categorical) variables.
4. Linear combination of explanatory variables can be used as a split.
5. The same variable can be used several times in different parts of the tree and with different threshold values.
6. CART has a built-in algorithm to deal with the missing values of a variable. The positions of missing points of a variable can be replaced by the points of so-called surrogate variables, so as to make split similar to the supposed split results so if the real variable has been used.
7. CART is not at all affected by the outliers, collinearities, heteroskedasticity, or distributional error structures that affect parametric procedures. Outliers are isolated into a node and thus have no effect on splitting. Contrary to situations in parametric modeling, CART makes use of collinear variables in "surrogate" splits.
8. CART has the ability to detect and reveal variable interactions in the data set.
9. CART can identify and explain the non-linear and complex relationships between the variables.
10. CART is not affected by modifications in variables, for example change into logarithmic or other forms, etc.

11. In the absence of a reliable theory that could guide a researcher, CART can be viewed as an exploratory, analytical tool to find out the factors and to reveal their effects. In this sense, it may be useful in constructing models under classical parametric analysis.
12. CART effectively deals with large datasets and the issues of higher dimensionality.
13. The tree-like structures produced are fairly easy to explain and understand.

Weaknesses

1. CART is a blunt instrument compared to many other statistical and analytical techniques. At each stage, the subdivision of data into two groups is based on only one value of only one of the potential explanatory variables. If an econometric model that appears to fit the data exists, and if its basic assumptions appear to be satisfied, that model would be preferable.
2. CART is not based on a probabilistic assumptions. There is no probability level or confidence interval associated with predictions, as well as there is no way to gage about significance of variables.
3. When linear relationships are described, CART is unfeasible to be used since it will make successive splits at different points of the same variable.
4. Target cases (for ex. crisis points) in terminal nodes of the tree may be in lesser quantities and often lead to incorrect conclusions[58].

Classification and Regression Trees for Predicting Currency Crises

Prediction of currency crises involves a process of explaining a dependent variable with the binary outcome by means of various explanatory factors, which can be both macroeconomic fundamentals and institutional indices. In addition, existing threshold effects and non-linear relationships of variables are intrinsic to the building of EWS. In other applied systems, the probability of the crisis is estimated using the "all else being equal" principle. However, the experience of currency crises (particularly the Asian crisis) suggests that they may arise even if the key macroeconomic fundamentals are at acceptable levels, which, when combined with other factors (structural-institutional, in particular) may lead to an undesirable outcome. Currency crises are events of purely a discrete nature hence their explanation through continuous econometrical relationships can lead to incorrect results.

CART models can be a systematic and nice solution to building EWS for currency crises that are characterized by above properties. Thus in the context of prediction of currency crises the CART methodology enables to:

- predict the probability of crises based on diverse sets and sometimes theoretically unjustified combinations of leading variables;
- determine the nature of the crisis and the inherent causes of it[59];
- determine an estimated model's out-of-sample predictive power and use the results right in the process of building of the relevant model;
- identify the importance of the explanatory variables and their relative contributions in the model, as well as nature of their intersections;
- estimate the lead-time of factors (how leading are the leading indicators);
- address the arbitrariness of the directions of effects of variables (for example, if an increase or decrease of oil prices away from certain threshold level is a concern);
- simplify the decision-making process related to crises since a few most important variables out of many studied will be included in the final model;
- get the turning points required for converting continuous variables into discrete ones (this was used in assessing conditional probabilities of the crises based on the Composite Index in the Signaling Approach).

In pursuit of building EWS for Armenia, several options have been under consideration, which can be divided into two major areas, panel models and Armenia-relevant-data-based models.

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[58] With the use of the software package like CART 6.0 ProEx it is possible to resolve this problem by figuring out which is the best option for the minimum size of a parent node to be split or the minimum number of cases in terminal nodes.
[59] Kaminsky (2003).

It should be noted that all CART modeling work was carried out using CART 6.0 ProEX software package developed by Selford Systems. As the only system in the world developed on a basis of the initial CART code created by the authors of this methodology, i.e. Breiman, Friedman, Olshen and Stone, it allows to address the problems related to the method at the core and a lot of supplementary and fundamental aspects developed by the firm with tight cooperation with the authors.

Panel Study: The panel of observation includes 21 countries of Eastern and Central Europe and the CIS region. In the Panel model, the indicator frequency is on a quarterly basis, due to the scarcity of their monthly data. As in the case with Signaling Approach, the crisis horizon is set to be 12 months, or 4 quarters. The building process of the *main model* through CART methodology has been conducted in two phases: at first the initial variant of the tree was constructed, then, after having carried out a few sensitivity and sustainability tests, the final tree was built which represents the basic signaling system for predicting currency crises in emerging countries in Europe as well as Armenia[60].

The initial tree constructed[61] which under the one standard deviation rule has 8 terminal nodes and good predictive properties, has been tested for sensitivity and sustainability. The results of the tests were used to build the ultimate model.

The final model tree is characterized by 37 terminal nodes as well as strong predictive properties: it predicts out-of-sample nearly 83 percent of currency crises (see the detailed discussion of the analytical study results in Appendix 8-A). As regards the best variables, it should be mentioned that the indicator *international oil price*[62] is unquestionably a leader. It is the main factor in splitting the root node of the tree. The *inflation* indicator, which was the leader in the Signaling Approach model is just the 4th here, letting behind such variables as budget deficit and asset prices[63]. There are not any absolute failures in this version of CART models in spite of the fact that variables such as elections, terms of trade and remittances posted to have shown lower predictive qualities[64] (the 'variable removal' LOVO sensitivity test results also support this statement, see Table A8-T-8).

In the main tree, terminal nodes 36 and 37 are very interesting: an extra analysis reveals that they contain cases related to the most recent currency crises of 2008-2009. Substantially different in nature from other crises, these deserve special treatment in a separate analysis. To this end, a total of 63 observations (in nodes 36 and 37) were separated and modeled individually (see results in Appendix 8-A *).

Albeit that model has predictive properties (merely 71% predictive accuracy out-of-sample) lower than the main model, it however tries to explain the main causes for the recent crises, which really boils down to financial and monetary variables, faster growth rates of broad money and domestic credit, in particular. Interestingly, the paper by Avetisyan (2010) reveals that the stability of the banking system and effective financial intermediation (bank concentration) are among key factors that determine the relative intensity of exchange rate depreciation pressures that countries experienced in the period 2008-2009[65].

Besides the main model presented, we have built a number of alternative models in pursuit of proposing different solutions to the problem of EWS.

Alternative 1: This model uses the EMP index version whereby standard deviations and means in respect of both index members and final index were built according to the principle of moving window, with its length of 2 years (see Figure 3-2). The generalized results of CART model constructed on a basis of this version of EMP index are provided in Appendix 8-B. This has 60 terminal nodes with predictive properties at a very low level – it predicts out-of-sample merely 65% of the crises. The leading variables here are dominated by such variables as oil price and asset price.

Alternative 2: This variant uses the 2-year moving window crisis threshold rule (see Figure 3-3). The model constructed through this method has 80 terminal nodes but, as was the case with the previous model, still provides weak predictive properties, an average 70% out-of-sample crisis prediction rate.

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[60] In addition to this model, we developed a number of other variants which we will refer to later on (see also Appendix 8-B, 8-C, 8-D, 8-E, 8-G).
[61] The results are not presented here but can be obtained from the author.
[62] Because the model considers currency crises of different generations and has a special focus on the recent events which are perhaps new generation crises, the indicator of international oil price is the factor that separates the previous and recent crises having occurred after 2000.
[63] This may be explained by the differences of datasets applied in the models (panel vs Armenia-relevant data).
[64] The variables such as short-term foreign debt and dollarization rank 8th and 9th, respectively.
[65] Avetisyan H. (2010), page 104.

Here, the best properties are attributable to the variable of *asset prices* whereas oil price ranks the third, staying behind the indicator of budget deficit (see Appendix 8-C).

Alternative 3: The above models, including the main one, are designed to predict currency crises within the signaling window, i.e. in the course of the upcoming 4 quarters. This alternative model proposes to use an instant approach and make forecasts as of any particular quarter. However, before the model would have been built, we had to determine the lags of variables. To this end, trees were constructed in consideration of various lags (up to 4 quarters) for each variable, by only including lags of any particular indicator as explanatory variables. Then, in view of the results of LOVO test (significance and sensitivity of CART variables), we selected the best lags for all variables[66]. These are provided in Table 3-4, showing that 9 out of the 24 indicators issue signals at least 3 quarters in advance.

Table 3-4: Best leading indicator lags

	Variable	Best lag
1	International reserves / GDP	4
2	Short-term foreign debt / International reserves	3
3	Foreign debt / GDP	1
4	Real exchange rate overvaluation	1
5	Current account / GDP	4
6	Exports	3
7	Domestic credit	3
8	M2 / International reserves	2
9	Inflation	1
10	Economic growth	1
11	Asset prices	2
12	Budget deficit / GDP	1
13	Remittances	4
14	Banks' foreign assets / foreign liabilities	4
15	Terms of trade	1
16	Democracy of political system	-
17	Elections	4
18	Credit / Deposits	1
19	World oil price	1
20	Difference in short-term and long-term interest rates	1
21	OECD country economic growth	4
22	Dollarization	2
23	Currency regime	-
24	Contagion effect	-

A model built by the use of variables with appropriate lags allows determining the probability of emergence of the crisis as of any particular quarter. In fact, this can be considered a dynamic model as it is also able to show the pattern with which that probability may change from quarter to quarter.

The results summed up in Appendix 8-D suggest that this model is prominent with its pretty good predictive properties, an average rate of 74% out-of-sample. The significance of variables is nearly similar to that of other models. A sudden improvement in the indicator of *dollarization* as well as clear advantage of the indicator of *asset prices* over other factors is noteworthy.

Alternative 4: As was noted earlier, using binary dependent variables may result in the loss of valuable information that continuous EMP index series contain. In this phase of modeling we try to solve this problem by using CART regression tree method (see Appendix 9). Also, this alternative approach would enable to determine how significant is the problem and how justified is the selected SD 1.645 rule when the continuous series are converted into the discrete series. Note, that the model was evaluated based on the previous, third, alternative (since that is the only one providing an instant approach, which is vital for continuous series) by substituting the dependent variable with the continuous series of the EMP index. The results summarized in Appendix 8-E, especially those pertinent to significance of variables, almost match with the results of the previous models. The only difference worth mentioning is the indicator *asset prices:* here it has lost its relevance to others. Increased role of the real exchange rate

[66] *The results can be obtained from the author.*

overvaluation is another matter of interest, which even in the initial stage of construction of the model (prior to the relevant adjustments based on sensitivity and sustainability tests) took a lead in the rank of leading variables.

However, these two options have significant differences with regard to the threshold levels of particular variables and how they come to appear in different parts of the terminal tree (see Annexes 8-D and 8-E). Moreover, after having the threshold levels of the candidate variables for the split of the root node compared with each other in the two models *(see Appendix 8-F)* it turned out that only 9 variables out of 24 were able to distribute the data at the same or roughly the same threshold level in either case. This provides evidence that there has been a loss of valuable information when the continuous variable was converted into a binary variable. This can be due to the choice of the crisis threshold determination rule (1.645 S.D.) on the one hand, and the lack of volatilities in the series on the other. It should be noted that the discrepancies in the results of the models can be due to the circumstance that absolute thresholds that distinguishes crisis episodes based on the EMP index in case of the same rule (1.645 S.D.) will differ from country to country (for example, points above 3.7 of the EMP index value are meant to be a crisis situations for Armenia but points above 8.2 will be considered crisis-relevant for Bulgaria), whereas the values of the entire panel will be treated equally in case of continuous EMP usage.

Armenia-relevant data models: These models used monthly data which covered a period of 1996-2009. The crisis window is for a 12-month span. Of the models built for Armenia, only the main version of the model based on the generalized structure of the EMP index is presented[67]. The construction of the model has gone in two phases, too, and its initial version[68] has been tested for sensitivity and sustainability. The test results were used to build the final model.

Built on Armenia data, the final CART model with its predictive properties even outstrips the main panel version, as it provides an average 92.5% explanation rate out-of-sample and 95.2% explanation rate in-sample (see Appendix 8-G). The model has 5 terminal nodes that contain explanatory variables such as credits/deposits, real exchange rate overvaluation, inflation and remittances. By factor importance, the indicators such as credits/deposits and banks' foreign assets/foreign liabilities take the lead. Quite interestingly, unlike the main panel model, from external explanatory factors explaining crises in Armenia, high significance has been attributed to the *contagion effect* rather than such indicators as *world economic growth* and *international oil price*[69]. All in all, countries, and Armenia among them, have to be open to the debate over considering domestic economic development factors as fundamental leading indicators in predicting currency crises.

Building combinations of models is among recent developments in the CART methodology. Researchers began looking at the advantage of constructing multiple trees back in early 1990s. The main point was that if one tree can have good forecasting features, then a few trees can provide better results. Leo Breiman was one of the authors of the CART methodology who addressed these issues. Very recently, he has introduced the theory of Random Forests that builds an effective predicting model as a result of combination of the best characteristics of individual trees. In practice, this idea has been realized in the framework of another software package which was again developed by Salford Systems. However, the decision-making mechanism based on multiple trees is embedded in its simplest version with the CART methodology in the form of combination of trees. Obviously, in the prediction process, different models can produce quite different results. The final decision comes in favor of taking the results as median. This principle is based on the usage of the CART Combine tool. There are two ways in CART to sum up the results: first to take them as median and second to improve each coming tree by using the unidentified part of the previous tree. Ignoring the main characteristics of each of them, let us note that we have carried out the modeling of combination of the trees based on the main tree by constructing a total of 100 candidate models. In future, this Combination Model will be used for making predictions. Just add that this combination of the models makes it possible to accurately predict more than 96% of the crises in-sample, whereas it was only 83% in the main model.

Types of currency crises: Next problem which allows solving the CART methodology is identification of the types of crises or the main sources of their emergence. We have used the classification of the types

[67] *The results of the others can be obtained from the author.*
[68] *The results can be obtained from the author.*
[69] *This indicator is among the key ones in almost all panel models.*

of currency crises provided in Kaminsky (2003)[70] and explored the specifics of all terminal nodes (which contain crisis observations) of the main model, having this in mind we also characterize the quarters prior to the crisis with a problem pertinent thereto (see Appendix 10). Then we identified the causes and the type of a particular crisis based on the features inherent to the period prior to each crisis occurred, as a simple attribution to the main cause that had been upmost shown up in the previous quarters. The results of the analysis suggest that around 30% of the currency crises observed in the emerging CEE and CIS countries in the 1990s and 2000s was due to the problems with budget deficit (classic, first generation models), and about 25% due to expansionary monetary policy and excess finance problems. It should be mentioned that self-fulfilling crises hold quite a large share in total, with 20% of them arisen due to an adverse environment and 13% due to unexplainable circumstances (excluding the recent crises). The currency crises (pressures) observed in Armenia in the period 1997-1998 have occurred exclusively due to an unfavorable environment although the crises in early 1997 and late 1998 can also be attributable to the budget deficit and monetary policy expansion issues, respectively[71].

Assessment of predictive properties of the models

Although the above discussions over predictive qualities of models are very promising, we find it necessary to refer to a number of classical standard statistics in order to evaluate the properties of the models with the binary variable. Moreover, these estimations can be used not only for the sake of comparison[72] with the results of other models common in the literature but also for producing combined model forecasts under the EWS in future[73].

In practice, the model results are evaluated by two groups of coefficients. The first is constructed based on the *confusion matrix* known from the Signaling Approach.

Confusion matrix

	Crisis period	Tranquil period
Prediction of crisis	A	B
Prediction of tranquil period	C	D

This matrix can be used to calculate various ratios to assess the "strength" of a signaling system. We will address some of them[74].

The *sensitivity* or *crisis coverage* ratio is designed to display the called portion of the crises. This, in essence, describes the probability that the signal would be pertinent to the crisis. It is calculated by the use of the matrix above:

$$P_1 = \frac{A}{A+C} \cdot 100\%$$

The *Specificity* ratio displays the share of accurately called tranquil periods. It is calculated as follows:

$$P_2 = \frac{D}{D+B} \cdot 100\%$$

Some authors are proposing to calculate the conditional probability of the crisis subject to the model forecast[75]

$$P_3 = \frac{A}{A+B} \cdot 100\%$$

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[70] *Kaminsky (2003), p. 11, 25.*
[71] *The detailed results about individual countries can be obtained from the author.*
[72] *This paper is for our best knowledge the first research in the field of building EWS through CART methodology, so we find it appropriate to address the main features of that methodology.*
[73] *If we weigh each model forecast by its predictive accuracy measure and get average weighted forecasts, we can have an idea of what kind of results to expect (for now, this is not possible to carry out for Armenia as there has been a total of two models evaluated so far; one may note that building CART combination models is somewhat a similar approach to this).*
[74] *Most of these ratios are provided in the paper by Apoteker, Barthelemy (2003) p. 6.*
[75] *Krznar (2004), p. 22.*

The latter, in essence, describes the probability that the crisis predicted would emerge.

The other ratios deal with misclassifications and correct classifications of all observations:

The model accuracy:

$$P_4 = \frac{A+D}{A+B+C+D} \cdot 100\%$$

Misclassification error:

$$P_5 = \frac{B+C}{A+B+C+D} \cdot 100\% = 1 - P_4$$

The second group of parameters to assess forecasting properties of the models are based on the predicted probability and statistical representation of its distribution. These have been proposed by Diebold and Rudebusch (1989) as signaling model accuracy assessment tools. There are a number of indicators used within this framework, and ratios such as Quadratic Probability Score and Logarithmic Probability Score are common.

The Quadratic Probability Score (QPS) is designed to assess existing divergence between the occurrence of the crisis and the prediction:

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

where: N is the number of observations or predictions, P is the probability of the model-estimated crisis in the signaling horizon (in the upcoming 12 months), R is the actually occurred crisis in the 12-month window, which make up 1 if the crisis has occurred and 0 if the crisis has not occurred.

The QPS test statistician takes values in the range [0, 2), where the value 0 points to the fact that the model has ideal properties.

The Logarithmic Probability Score (LPS) depends exclusively on the probability forecasted. It is a more generalized rule of assessment where bigger errors of prediction, while compared with the QPS score, are treated more severely. It is calculated as follows:

$$LPS = \frac{1}{N}\sum_{t=1}^{N} [(1 - R_t)\ln(1 - P_t) + R_t \ln(P_t)]$$

This statistic takes values in the range $[0, \infty)$: the lower they are the higher the predicting properties of the model are.

Apart from these main scores, there is a great diversity of coefficients[76] known in the literature. Among most prominent of them is the Pesaran-Timmermann Test which allows determining the statistical significance of deviations from the predictions made. It is designed to explore statistical distribution of comparison of predictions with a random selection (random walk) model.

Let us refer to the properties of the models we built, using the above scores. It should be noted that most indicators under the CART methodology were calculated when the model was still under construction process, by the use of CART built-in algorithms, therefore, they will be provided here. Some basic models – CART main panel model, CART Armenia model and Signaling Approach Model with its two composite index versions – were chosen for assessing the predictive properties. Table 3-5 shows that both CART and Signaling Approach models have excellent predicting qualities; particularly, in all variants the QPS does not exceed the value 0.2 and is almost close to 0 in Armenia-relevant data models (CART Armenia, Signaling Approach Models).

[76] *Part of them is provided in Budsayaplakorn, Dibooglu, Mathur (2006), p. 11-12.*

Table 3-5: Model predictive capacities

	CART main panel	CART Armenia	Signal approach: Composite Index 1		Signal approach: Composite Index 2 (instant approach)	
			threshold 20%	threshold 50%	threshold 25%	threshold 50%
Share of crises called	96.36	95.74	97.06	94.12	100.00	60.00
Share of tranquil periods called	79.67	94.64	91.13	95.97	89.19	98.65
Crisis probability conditional on forecast	60.88	88.24	75.00	86.49	38.46	75.00
Total predictive accuracy	83.80	94.97	92.41	95.56	89.87	96.20
Misclassifications	16.20	5.03	7.59	4.43	10.13	3.80
QPS	0.1874	0.0699	0.0791		0.0585	
LPS	0.3231	0.2469	0.3321		0.5412	

What is interesting either is that Table 3-5 can indicate the prevalence of predictive properties of Armenia-relevant data models over the panel models. This may be determined by both the shortness of time series (monthly data for 1996-2009) and the scarcity of crises in the period under review, most part of which is distributed at the opening and closing ends of the series. These results, however, are not in conflict with the conventional wisdom that models built by one-country data can have stronger properties in comparison with the panel models[77].

Obviously, for comparison of predictive properties of the models, their main parameters (data, length of the prediction horizon, and etc.) should be compatible. Therefore, when results of CART and Signaling Approach models are to be compared, the models with 50% threshold level of Composite Index 1 of the Signaling Approach and CART Armenia should be considered. These are compatible in terms of both time series, which are relevant to monthly Armenia data, and the length of the signaling horizon, which is 12 months in all models, and the threshold level as Prior Equal has been used in CART that implies assigning a crisis class to the nodes with crisis class share above 50%.

The comparison of the two models above-mentioned makes it clear that these almost do not vary from each other: though for the called share of the crises CART version outperforms the Signaling Approach Model, the latter has advantage in terms of the total prediction accuracy and misclassifications. The quadratic and logarithmic probability scores give some advantage to the CART method, nonetheless.

To allow for the comparison of predictive properties of CART model to the other models observed in different research and policy papers Table 3-6 summarizes in-sample and out-of-sample predictive properties of these techniques[78].

Table 3-6: EWS model property comparison matrix

	CART main panel	Signaling Approach	Probit	Markov Switching Model	Artificial Neural Networks
Author		Kaminsky, Lizondo, Reinhart (1998), Source: *Berg, Borensztein, Pattillo (2005)*	*Berg, Borensztein, Pattillo (2005)*	*Abiad (2003)*	*Peltonen (2006)*
In-Sample (%)					
Share of crises called	96	60	63	65	46
Share of tranquil periods called	80	72	79	89	99
Probability of crisis, conditional on forecast	61	29	37	73	75
Total predictive accuracy	84	70	76	81	92
Misclassifications	16	30	24	19	9
Out-of-Sample (%)					
Share of crises called	83	58	31		4
Share of tranquil periods called	78	79	80		99
Probability of crisis, conditional on forecast	55	35	22		29
Total predictive accuracy	79	76	72		89
Misclassifications	21	24	28		11

[77] *Abiad (2003), p. 40.*
[78] *The observation covered the results of the works that contain panel data, especially where the panel includes CEE countries.*

Quadratic Probability Score (QPS)					
Author		*Bruggemann, Linne (2002)*	*Shardax (2003)*		*Peltonen (2006)*
	0.1874	0.3310	0.1295-0.1708		0.0459
ROC criterion (area under ROC curve)					
Author		*Peltonen (2006)*			*Peltonen (2006)*
In-Sample	0.9185	0.7841			0.7226
Out-of-Sample	0.8227	0.6335			0.4687

Source:

1. *Berg, Borensztein, Pattillo (2005) – reestimates the Kaminsky, Lizondo, Reinhart (1998)'s Signaling Model (monthly data of 20 countries for the period 1970-2001, signaling horizon 24 months) and Berg, Patillo (1999)'s probit models (same parameters as in the Kaminsky, Lizondo, Reinhart (1998) signaling approach).*
2. *Abiad (2003): monthly data of 5 developing Asian countries for the period 1972-1999, with the signaling horizon of 12 months.*
3. *Peltonen (2006): monthly data of 24 developing countries for the period 1980-2001, with the signaling horizon of 3 months.*
4. *Bruggemann, Linne (2002): monthly data of 5 CEE countries for the period 1993-2001, with the signaling horizon of 18 months.*
5. *Shardax (2003): quarterly data of 12 CEE countries for the period 1992-2002, with the signaling horizon of 24 months.*

Though the models observed vary by the key parameters, the length of the signaling horizon in particular, we need to emphasize that CART and Artificial Neural Network models are frontrunners among the methodologies currently in use. It is worth mentioning that CART model outperforms all its rivals for the crisis prediction ability out-of-sample as well as for the ROC criterion both in-sample and out-of-sample. Artificial Neural Networks enjoy a greater predictive accuracy rate when they deal with predicting tranquil periods, whereas they report weaknesses in predicting crisis situations, in comparison with all other model versions.

So, modern models, i.e. classification trees and artificial neural networks, best fit to be used for building state-of-the-art early warning systems as they are designed to identify all streamlined flows of valuable information. However, while neural networks operate at the "black box" principle, the CART models enable to figure out relationships and properties of fundamental variables of the model thus taking a lead in the competition with rivals.

CONCLUSION

There is a consensus among economists that early warning systems, however complex and sophisticated they can be, do not provide for the possibility to predict currency crises in an absolute accuracy. Even those researchers who are involved in building such frameworks, the author of this paper among them, realize that they are just important supplements and auxiliary tools built based on certain modeling principles and cannot substitute detailed economic analysis of countries' vulnerabilities to crises. However, an early warning systems in place can be a cornerstone in the further effort for predicting and assessing currency crises or substantial exchange rate pressures in Armenia.

Concluding remarks of this research are especially important for taking further steps in the analytical work in regard to crises in Armenia:

- Almost all variables chosen are prominent with their best predictive properties for the economy of Armenia; as such, the most significant leading indicators include *budget deficit*, *credit growth*, *inflation*, *foreign debt*, and *banking liabilities*.
- The two composite indices of the signaling approach can be applicable not only for estimating conditional probability of crises but also for identifying and predicting relatively intense currency pressure cycles.
- The panel models provide evidence that the currency crises of 2008-2009 were different by nature from the ones observed previously in developing countries, and financial and monetary variables had played a decisive role in them.

- The analysis of leading indicators shows that 9 variables out of 24 are able to issue signals about the forthcoming crisis at least 3 quarters in advance.
- Building combined model predictions is vital for policy decision-making.
- Most of the crises observed in developing countries of Europe were attributable to the budget deficit and excess finance problems. Self-fulfilling crises constitute a significant share.
- The models built in this paper have strong predictive properties and can be used in forecasting currency as well as financial crises in Armenia.
- The model, constructed through the CART methodology, with its predictive properties considerably outperforms all other types of models common in the literature.

REFERENCE

1. Avetisyan H., "Prediction of Currency Crises in the Republic of Armenia: the Results from Signaling Approach", Yerevan University Periodical ("Banber"), 2 (128), 2009, pp. 150-158.
2. Avetisyan H., "Global Exchange Rate Movements During The Financial Crisis", Periodical of Armenian State University of Economics ("Banber"), 1(19), 2010, pp. 93-104.
3. Avetisyan H., "The Global Financial Crisis and Depreciation Pressures in Developing Countries", Armenia: Finance and Economy, #6-7 (107-108), May-June 2009, pp. 12-14
4. Avetisyan H., "A New Generation Currency Crisis", The economies of Republic of Armenia and Russian Federation During World Economic Crisis: Problems and Prospects of Developments, International Conference Notes, Yerevan, 2010, pp. 220-229
5. Abiad Abdul, "Early-Warning Systems: A Survey and a Regime-Switching Approach", IMF WP/03/32, February 2003.
6. Aghion Philippe, Bacchetta Philippe, Banerjee Abhijit, "A simple model of monetary policy and currency crisis", European Economic Review, 44 (2000), pp. 728-738.
7. Andriyashin Anton, "Financial Applications of Classification and Regression Trees", A Master Thesis, CASE, Humboldt University, Berlin, March 2005.
8. Apoteker Thierry, Barthelemy Sylvain, "Genetic Algorithms and Financial Crises in Emerging Markets", TAC Financial, June 2001.
9. Apoteker Thierry, Barthelemy Sylvain, "Predicting Financial Crisis in Emerging Markets using a Composite Non-Parametric Data Mining Model", TAC Financial, 2003.
10. Basurto Gabriela, Ghosh Atish, "The Interest Rate-Exchange Rate Nexus in Currency Crisis", IMF Staff Papers, Vol. 47, Special Issue, 2001.
11. Berg Andrew, Borensztein Eduardo, and Pattillo Catherine, "Assessing Early Warning Systems: How Have They Worked in Practice?", IMF Staff Papers, Vol. 52, Number 3, 2005, pp. 462-502.
12. Bruggemann Axel, Linne Thomas, "Are the Central and Eastern European Transition Countries still vulnerable to a Financial Crisis? Results from the Signals Approach", IWH-Discussion Papers No.157., 2002.
13. Bubula Andrea, Otker-Robe Inci, "Are Pegged and Intermediate Exchange Rate Regimes More Crisis Prone?", IMF WP/03/223, November 2003.
14. Bubula Andrea, Otker-Robe Inci, "The Evolution of Exchange Rate Regimes Since 1990: Evidence from De Facto Policies", IMF WP/02/155, September 2002.
15. Budsayaplakorn Saksit, Dibooglu Sel, Mathur Ike, "Can macroeconomic indicators predict a currency crisis? Evidence from selected Southeast Asian countries", Department of Finance Southern Illinois University, 2006.
16. Burnside Craig, Eichenbaum Martin, Rebelo Sergio, "Currency Crisis Models", The New Palgrave: A Dictionary of Economics, 2nd Edition, February 2007.
17. Calvo Guillermo A., Reinhart Carmen M., "Fear of Floating", NBER Working Paper 7993, November 2000.
18. "CART: Tree-Structured Non-Parametric Data Analysis", San-Diego, CA: Salford Systems, 2001.

19. Chamon Marcos, Manasse Paolo, Prati Alessandro, "Can We Predict the Next Capital Account Crisis", IMF Staff Papers, Vol. 54, No. 2, 2007, pp. 270-305.
20. Chang Roberto, Velasco Andres, "Financial Crises in Emerging Markets: A Canonical Model", Federal Reserve Bank of Atlanta, Working Paper, 98-10, July 1998.
21. Corsetti Giancarlo, Pesenti Paolo, Roubini Nouriel, "What caused Asian currency and financial crisis?", NBER Working Paper, September, 1998.
22. Diebold Francis X., Rudebusch Glenn D., "Scoring the Leading Indicators", The Journal of Business, Vol. 62, Jul. 1989, pp. 369-391
23. Edison Hali J., "Do Indicators of Financial Crisis Work? An Evaluation of an Early Warning System", International Journal of Finance and Economics, 8 (2003), pp. 11-53.
24. Eichengreen, Barry, Rose Andrew K, Wyplosz Charles, "Contagious Currency Crisis." NBER Working papers 5681, July 1996.
25. Eliasson Ann-Charlotte, Kreuter J. Christof , "On Crisis Models: An alternative crisis definition", Deutsche Bank, Research Note RN-01-1, May 2001.
26. Esquivel Gerardo, Larrain B Felipe, "Explaining Currency Crisis", HIID, Harvard, June 1998.
27. Fischer Stanley, "Exchange Rate Regimes: Is the Bipolar View Correct?", Journal of Economic Perspectives, Vol. 15, No. 2, 2001, pp. 3-24.
28. Flood Robert, Marion Nancy, "Perspectives on the Recent Currency Crisis Literature", International Journal of Finance and Economics, Vol. 4, No. 1, January 1999, pp. 1-26.
29. Feridun Mete, "Speculative Attacks under Financial Liberalization", Department of Economics, Loughborough University, Leicestershire, 2006, www.caei.com.ar
30. Gerlach Stefan, Smets Frank, "Contagious Speculative Attacks", BIS Working Paper, No. 22, September 1994.
31. Girton Lance, Roper Don, "A Monetary Model of Exchange Market Pressure Applied to the Postwar Canadian Experience", The American Economic Review, Vol. 67, No. 4, Sept. 1977, pp. 537-548.
32. Ghosh Swati, Ghosh Atish, "Structural Vulnerabilities and Currency Crises", IMF WP/02/9, January 2002.
33. Goldstein Morris, "Emerging Market Financial Crises: Lessons and Prospects", Speech delivered at the 25th Anniversary Membership Meeting of the Institute of International Finance, Washington, DC October 20, 2007.
34. Hattori Masazumi, "On Determinants of the Depth of Currency Crisis: Fundamentals, Contagion, and Financial Liberalization", Bank of Japan, International Department Working Paper Series 02-E-2, September 2002.
35. Hawkins John, Klau Marc, "Measuring Potential Vulnerabilities in Emerging Market Economies", BIS Working Paper, No. 91, October 2000.
36. Kaminsky Graciela, "Varieties of Currency Crises" , NBER Working Paper 10193, December 2003.
37. Kaminsky Graciela, "Currency and Banking Crisis: The Early Warnings of Distress", Board of Governors of the Federal Reserve System, International Finance Discussion Paper No. 629, October 1998.
38. Kaminsky Graciela L., Reinhart Carmen M., "The Twin Crises: The Causes of Banking and Balance-of-Payments Problems", The American Economic Review, Vol.89, No. 3, June 1999.
39. Kaminsky Graciela, Lizondo Saul, and Reinhart Carmen M., "Leading Indicators of Currency Crises", *IMF Staff Papers*, Vol. 45, No. 1 (March), 1998, pp. 1-48.
40. Knedlik Tobias and Scheufele Rolf, Three methods of forecasting currency crises: Which made the run in signaling the South African currency crisis of June 2006?, December 2007, IWH-Discussion Papers, Nr. 17, 2007, pp. 1-28.
41. Krugman Paul R., "A Model of Balance-of-Payments Crises", Journal of Money, Credit and Banking, Vol. 11, No. 3, Aug. 1979, pp. 311-325.
42. Krugman Paul R., Obstfeld Maurice, "International Economics: Theory and Policy", 5th Edition, An imprint of Addison Wesley Longman, 2000.
43. Krznar Ivo, "Currency Crisis: Theory and Practice with Application to Croatia", Croatian National Bank, August 2004.
44. Kumar Moham, Moorthy Uma, Perraudin William, "Predicting Emerging Market Currency Crashes", Journal of Empirical Finance, 10 (2003), pp. 427-454.

45. Lewis Roger J., "An Introduction to Classification and Regression Tree (CART) Analysis", Harbor-UCLA Medical Center, Department of Emergency Medicine, 2000.
46. Liaw Andy, Wiener Matthew, "Classification and Regression by Random Forest", R-News, Vol. 2/3, December 2002, pp. 18-22.
47. Li Jie, Rajan Ramkishen S., Willet Thomas, "Measuring Currency Crisis using Exchange Market Pressure Indices: The Imprecision of Precision Weights", October 2006.
48. Mecagni Mauro, Atoyan Ruben, Hoffman David, Tzanninis Dimitri, "The Duration of Capital Account Crises-An Empirical Analysis", IMF WP/07/258, November 2007.
49. Milesi-Ferretti Gian Maria, Razin Assaf, "Current Account Reversals and Currency Crises: Empirical regularities", in Krugman P., "Currency Crises", Chicago Press, 2000, pp. 285-325.
50. Nag Ashok K., Mitra Amit, "Neural Networks and Early Warning Indicators of Currency Crisis", Reserve Bank of India, 1999.
51. Obstfeld Maurice, "Rational and Self-Fulfilling Balance-of-Payments Crises", NBER Working Paper, No. 1486, 1986.
52. Obstfeld Maurice, "Models of Currency Crises With Self-Fulfilling Features", NBER Working Paper 5285, October 1995
53. Peltonen Tuomas A., "Are Emerging Market Currency Crisis Predictable", ECB Working Paper Series, No. 571, January 2006.
54. Racaru Irina, Copaciu Mihai, Lapteacru Ion, "Early Warning Systems on Currency Crisis", National Bank of Romania, Occasional Papers N5, June 2006.
55. Reinhart Carmen M., Rogoff Kenneth S., „The Modern History of Exchange Rate Arrangements: A Reinterpretation", The Quarterly Journal of Economics, Vol. CXIX, Issue 1, February 2004, pp. 1-48.
56. Salant Stephen W., Henderson Dale W., "Market Anticipations of Government Policies and the Price of Gold", The Journal of Political Economy, Vol. 86, No. 4, Aug 1978, pp. 627-648.
57. Scherbakov Alexander, "Generalized Approach to Currency Crisis Risk Analysis", A thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts in Economics, National University of "Kiev-Mohyla Academy", 2000.
58. Shardax Franz, "An Early Warning Model for Currency Crises in Central and Eastern Europe", Capital Invest, 2003.
59. Steinberg Dan, Golovnya Mikhail, "CART 6.0 User's Guide", San-Diego, CA: Salford Systems, 2007.
60. Tinakorn Pranee, "Indicators and Analysis of Vulnerability to Currency Crisis: Thailand", Thailand Development Research Institute, September, 2002.
61. Toth Jan, "Vulnerability Index – Guessing the Probability of a Currency Crisis Central European Experience", ING Bank, Slovakia, 2002.
62. Vlaar Peter J G, "Early warning systems for currency crises", Econometric Research and Special Studies Department, Netherlands Bank, 2000.
63. Won-Am Park, Indicators and Analysis of Vulnerability to Economic Crisis: Korea, Hongik University Seoul, EADN, Korea, 2002.
64. Yilmazkuday Hakan, "The Effects of Currency Crisis in Emerging Markets on the Industrial Sector: An Alternative Regime-Shifting Approach", Emerging Markets Finance and Trade, October, 2007.
65. Yohannes Yisehac, Webb Patrick, "Classification and Regression Trees, CART: A User Manual For Identifying Indicators of Vulnerability to Famine and Chronic Food Insecurity", International Food Policy Research Institute, Washington D.C., 1999.

Appendix 1: Existing definitions of currency crises

<table>
<tr><th></th><th>Main sources</th><th>Definition of the crisis</th><th>Data</th></tr>
<tr><td>1.</td><td>Kaminsky, Lizondo, Reinhart (1998)</td><td>The Exchange market pressure index
$I_1 = \%\Delta e - \frac{\sigma_e}{\sigma_r}\%\Delta r$ ' $I_2 = \frac{1}{\sigma_e}\%\Delta e - \frac{1}{\sigma_r}\%\Delta r$ ' $I_3 = \frac{\sigma_r}{\sigma_e + \sigma_r}\%\Delta e - \frac{\sigma_e}{\sigma_e + \sigma_r}\%\Delta r$
$I > \mu + K * \sigma_I$
e - exchange rate, r - international reserves, σ_e - standard deviation of exchange rate,
σ_r - standard deviation of reserves, μ - index average, σ_I - standard deviation of index,
K = 1.1, 1.28, 1.5, 1.645, 1.96, 2.0, 2.5, 3.0</td><td>Monthly data of 20 countries, for the period 1970-1995</td></tr>
<tr><td>2.</td><td>Kumar, Moorthy, Perraudin (2003)</td><td>1. Unexpected depreciation
$100\left[\frac{e_{t+\Delta} - e_t}{e_t}\right]\left[\frac{1 + r_t^*}{1 + r_t}\right] > \gamma_1$
r_t^* - external interest rate, r_t - domestic interest rate,
e_t - exchange rate, γ_1 - marginal value which is set to be either 5% or 10%
2. General devaluation crisis
$100\left[\frac{e_{t+\Delta} - e_t}{e_t}\right] > \gamma_2$ and $\left[\frac{e_{t+\Delta} - e_t}{e_t}\right] > (1 + \gamma_3)\left[\frac{e_t - e_{t-\Delta}}{e_{t-\Delta}}\right]$
γ_3 - accepted to be 100%, i.e. doubling of the rate of devaluation, γ_2 - 5% or 10%</td><td>Monthly and yearly data of 32 developing countries, for the period 1985-1999</td></tr>
<tr><td>3.</td><td>Hawkins, Klau (2000)</td><td>1. The Exchange market pressure index
$I_1 = W_1 \cdot xrm + W_2 \cdot xra + W_3 \cdot r + W_4 \cdot res$
xrm - 3-month depreciation of the exchange rate (in percent),
xra - yearly depreciation of the exchange rate (in percent),
r- 3-month interest rate less annualized inflation previous 6 months,
res - 3-month change of the 12-month moving average of reserves to imports ratio
Indicator values are chosen according to the following table:
<table>
<tr><th colspan="2">Indicator</th><th rowspan="2">–2</th><th rowspan="2">–1</th><th rowspan="2">0</th><th rowspan="2">1</th><th rowspan="2">2</th></tr>
<tr><th>Code</th><th>Weight</th></tr>
<tr><td>xrm</td><td>W_1</td><td>10 < x</td><td>2 < x ≤ 10</td><td>2 ≥ x > –3</td><td>– 3≥ x > –8</td><td>x ≤ –8</td></tr>
<tr><td>xra</td><td>W_2</td><td>20 < x</td><td>5 < x ≤ 20</td><td>5 ≥ x > –5</td><td>–5 ≥ x > –20</td><td>x ≤ –20</td></tr>
<tr><td>r</td><td>W_3</td><td></td><td></td><td>x ≤ 2</td><td>2 < x ≤ 4</td><td>x > 4</td></tr>
<tr><td>res</td><td>W_4</td><td>8 < x</td><td>4 < x < 8</td><td>4 ≥ x > –4</td><td>–4 > x ≥ –8</td><td>x < –8</td></tr>
</table>
so that the maximum value of the index equals 10, that is $W_1=W_2=W_3=W_4=1.25$</td><td>Quarterly data of 24 developing countries, for the period 1993-1998</td></tr>
</table>

2. External vulnerability index

$$I_2 = W_1 \cdot reer + W_2 \cdot cgdp + W_3 \cdot gx + W_4 \cdot debt + W_5 \cdot gdebt + W_6 \cdot stdebt$$

$reer$ - real effective exchange deviation from the average (in percent),

$cgdp$ - current account/GDP,

gx - annual export growth deviation from the average annual growth,

$debt$ - foreign debt/GDP,

$gdebt$ - 8 quarters' growth of the above indicator,

$stdebt$ - short-term foreign debt/reserves

Indicator values are chosen according to the following table:

Indicator		−2	−1	0	1	2
Code	Weight					
reer	W_1	$-20 \geq x$	$-20 < x \leq -10$	$-10 < x \leq 10$	$10 < x \leq 20$	$x > 20$
cgdp	W_2	$x > 4$	$2 < x \leq 4$	$-2 < x \leq 2$	$-4 < x \leq -2$	$-4 \geq x$
gx	W_3	$x > 10$	$10 \leq x < 5$	$0 < x \leq 5$	$-5 < x \leq 0$	$-5 \geq x$
debt	W_4		$x \leq 20$	$20 < x \leq 30$	$30 < x \leq 40$	$x > 40$
gdebt	W_5	$-10 \geq x$	$-10 < x \leq 0$	$0 < x \leq 10$	$10 < x \leq 15$	$x > 15$
stdebt	W_6		$x \leq 50$	$50 < x \leq 100$	$100 < x \leq 150$	$x > 150$

so that the maximum value of the index equals 10, that is $W_1=W_2=W_3=W_4= W_5 =W_6 =5/6$

4.	Won-Am Park (2002)	*The Exchange market pressure index* $I = \frac{1}{\sigma_e}\Delta e + \frac{1}{\sigma_i}\Delta i - \frac{1}{\sigma_r}\Delta r$ $I > \mu + 1.1 * \sigma_I$ Δi - interest rate change	Monthly data of South Korea, for the period 1990-1997
5.	Eichengreen, Rose, Wyplosz (1996)	$I = \frac{1}{\sigma_e}\%\Delta e + \frac{1}{\sigma_i}\Delta(i - i^*) - \frac{1}{\sigma_r}(\%\Delta r - \%\Delta r^*)$ Non-weighted version is discussed, as well. i^* Ë $\%\Delta r^*$- respectively, change in interest rate and reserves of foreign country (Germany). $I > \mu + 1.5 * \sigma_I$	Quarterly data of 20 developed countries, for the period 1959-1993
6.	Eliasson, Kreuter (2001)	*Continuous Definition of crisis* Consists of the simple sum of deviations from long-term averages of the *change in exchange rate, changes in the real interest rate* and *the level of real interest rate,* The index is built as a result of the 5-step process: Step 1: Construct the histogram of each indicator. Step 2: Compare the observed distribution with the Gaussian Distribution and get the differences (deviations). Step 3: Compare the distribution of deviations of crisis points (right segment of distribution) with a certain functional form that best describes it. As a result, you will get a distribution function that describes the crises, which is in the (0,1) interval. Step 4: Get functions of 3 variables together. Step 5: The series produced will need to be smoothed out with exponential weighting moving average technique, which smoothens the most remote areas (outlayers) of the series and suggests a gradual transition of the crisis into a peaceful period..	Quarterly data of 10 developing countries, for the period 1990-2000
7.	Esquivel, Larrain (1998)	1. $\Delta^3\varepsilon > 15\%$ or 2. $\Delta^1\varepsilon > 2.54\sigma_{\Delta\varepsilon}$ Ë $\Delta^1\varepsilon > 4\%$ $\Delta^3\varepsilon$ - 3-month cumulative change of the real exchange rate $\Delta^1\varepsilon$ - monthly change of the real exchange rate $\sigma_{\Delta\varepsilon}$ - $\Delta^1\varepsilon$ standard deviation	Annual date of 30 developed and developing countries, for the period 1975-1996
8.	Shardax (2003)	At least 20% depreciation of the nominal exchange rate during 10 trading days.	Quarterly data of 12 Eastern and Central European countries, for the period 1992-2002
9.	Tinakorn (2002)	3-month cumulative depreciation of the nominal exchange rate > 15% or 3-month cumulative reduction in net international reserves >15%	Monthly data of Thailand, for the period 1992-2000
10.	Goldfaja, Valdes (1997) Source: Tinakorn (2002)	1. Nominal exchange rate depreciation > 1.96* exchange rate standard deviation or 2. Exchange rate depreciation > 2%+1.5* previous month's depreciation	Monthly data of 26 countries, for the period 1984-1997

11.	Engwatana (1999) Source: Tinakorn (2002)	1. One-month cumulative growth of the nominal exchange rate >10% 2. Monthly deviation of the Forward Premium from its 3-month moving average >10%	Monthly and quarterly data of Thailand, for the period 1990-1998
12.	Poonpatpibul, Ittisupornrat (2001) Source: Tinakorn (2002)	3-month cumulative growth of the nominal exchange rate >15%	Monthly data of Thailand, for the period 1990-2000
13.	Milesi-Ferretti, Razin (2000)	1. Annual depreciation of the nominal exchange rate ≥ 25%, which is more than 10pp higher from the previous year's depreciation: $I_t \geq 25\%$ and $I_t - I_{t-1} \geq 10\%$, where: $I_t = \ln(e_t - e_{t-1})$ e_t - nominal exchange rate 2. $I_t \geq 25\%$ and $I_t - I_{t-1} \geq 100\%$ and $I_{t-1} \leq 40\%$ 3. $I_t \geq 15\%$ and $I_t - I_{t-1} \geq 10\%$ and $I_{t-1} \leq 10\%$ 4. $I_t \geq 15\%$ and $I_t - I_{t-1} \geq 10\%$ and $I_{t-1} \leq 10\%$ and if the exchange rate was fixed a year before the crisis.	Annual data of 105 developing countries, for the period 1975-1996
14.	Mecagni, Atoyan, Hoffman, Tzanninis (2007)	*The capital account crisis index:* $IKAC_t = -(FX_t - FX_t^{trend}) - \ln(NEER_t / NEER_{t+1}) + S_t - K_t$ FX - international reserves $NEER$ - nominal effective exchange rate S - spread of government bonds K - net capital inflow/GDP	
15.	Moreno (2000) Source: Bubula, Otker-Robe (2003)	Annualized depreciation of the nominal exchange rate ≥ 25% $I_t \geq 25\%$, where: $I_t = \ln(e_t - e_{t-1}) * 100\%$ and $I_t > \bar{I}_{12m} + 3.0 * \sigma_{I,12m}$, where: $\bar{I}_{12m}$ - average of changes in the previous 12-month period $\sigma_{I,12m}$ - standard deviation of ratios calculated for the same 12-month period	Monthly data of 7 Eastern Asia countries, for the period 1974-1999
16.	Glick, Hutchinson (1999) Source: Bubula, Otker-Robe (2003)	$I = \%\Delta\varepsilon - \frac{\sigma_e}{\sigma_r}\%\Delta r$, where: ε - real exchange rate $I > \mu + 2.0 * \sigma_I$ or $\%\Delta\varepsilon > 15\%$, provided that it is well above the same indicator of the previous month and $\%\Delta\varepsilon >$ country-specific average + $2.0 * \sigma_{\%\Delta\varepsilon}$, provided that it is also ≥ 5%	Month data of 21 developed and 69 developing countries, for the period 1975-1997
17.	Zhang (2001) Source: Abiad (2003)	Separate threshold levels for exchange rate and reserves: threshold is 3 standard deviations away from the average, where standard deviation is calculated by the 3-year moving window.	Monthly data of 4 Eastern Asia countries, for the period 1993-1997

Appendix 2: Basic characteristics and results of several studies about currency crises

<table>
<tr><th></th><th>Author</th><th>Definition of the crisis</th><th>Data</th><th>Method</th><th>Indicators (significant)</th></tr>
<tr><td>1.</td><td>Kaminsky, Lizondo, Reinhart (1998)</td><td>The Exchange market pressure index
$I = \%\Delta e - \frac{\sigma_e}{\sigma_r}\%\Delta r$
$I > \mu + 3.0 * \sigma_I$
e - exchange rate, r - international reserves,
σ_e - standard deviation of the exchange rate,
σ_r - standard deviation of the interest rate,
μ - index average
σ_I - standard deviation of the index</td><td>Monthly data of 20 countries, for the period 1970-1995</td><td>Signaling approach</td><td>1. Real exchange rate deviation from equilibrium,
2. Bank crises
3. Exports
4. Asset prices
5. M2/reserves
6. Economic growth
7. M1 surplus
8. International reserves
9. M2 multiplier
10. Domestic credit/GDP
11. Real interest rate
12. Terms of trade</td></tr>
<tr><td>2.</td><td>Kumar, Moorthy, Perraudin (2003)</td><td>1. Unexpected depreciation
$100\left[\frac{e_{t+\Delta}-e_t}{e_t}\right]\left[\frac{1+r_t^*}{1+r_t}\right] > \gamma_1$
r_t^* - external interest rate, r_t - domestic interest rate, e_t - exchange rate,
γ_1 - marginal value which is set to be either 5% or 10%
2. General devaluation crisis
$100\left[\frac{e_{t+\Delta}-e_t}{e_t}\right] > \gamma_2$ and $\left[\frac{e_{t+\Delta}-e_t}{e_t}\right] > (1+\gamma_3)\left[\frac{e_t-e_{t-\Delta}}{e_{t-\Delta}}\right]$
γ_3 - accepted to be 100%, i.e. doubling the rate of devaluation,
γ_2 - 5% or 10%</td><td>Monthly and annual data of 32 developing countries, for the period 1985-1999</td><td>Logit model</td><td>1. 12-month change in international reserves
2. Deviation of real GDP from the trend
3. Import coverage
4. Public debt/Total debt
5. Dummy variable of regional contagion</td></tr>
<tr><td>3.</td><td>Hawkins, Klau (2000)</td><td>1. The Exchange market pressure index
$I_1 = W_1 \cdot xrm + W_2 \cdot xra + W_3 \cdot r + W_4 \cdot res$
xrm - 3-month depreciation of the exchange rate (in percent),
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<tr><th>Code</th><th>Weight</th><th colspan="5"></th></tr>
<tr><td>xrm</td><td>W_1</td><td>10 < x</td><td>2 < x ≤ 10</td><td>2 ≥ x > –3</td><td>– 3≥ x > –8</td><td>x ≤ –8</td></tr>
<tr><td>xra</td><td>W_2</td><td>20 < x</td><td>5 < x ≤ 20</td><td>5 ≥ x > –5</td><td>–5 ≥ x > –20</td><td>x ≤ –20</td></tr>
<tr><td>r</td><td>W_3</td><td></td><td></td><td>x ≤ 2</td><td>2 < x ≤ 4</td><td>x > 4</td></tr>
<tr><td>res</td><td>W_4</td><td>8 < x</td><td>4 < x < 8</td><td>4 ≥ x > –4</td><td>–4 > x ≥ –8</td><td>x < –8</td></tr>
</table>
so that the maximum value of the index equals 10, that is $W_1=W_2=W_3=W_4=1.25$
2. External vulnerability index
$I_2 = W_1 \cdot reer + W_2 \cdot cgdp + W_3 \cdot gx + W_4 \cdot debt + W_5 \cdot gdebt + W_6 \cdot stdebt$
$reer$ - real effective exchange deviation from the average (in percent),
$cgdp$ - current account/GDP,
gx - annual export growth deviation from the average annual growth,
$debt$ - foreign debt/GDP,
$gdebt$ - 8 quarters' growth of the above indicator,
$stdebt$ - short-term foreign debt/reserves
Indicator values are chosen according to the following table:
<table>
<tr><th colspan="2">Indicator</th><th>–2</th><th>–1</th><th>0</th><th>1</th><th>2</th></tr>
<tr><th>Code</th><th>Weight</th><th colspan="5"></th></tr>
<tr><td>$reer$</td><td>W_1</td><td>–20 ≥ x</td><td>–20 < x ≤ – 10</td><td>–10 < x ≤ 10</td><td>10 < x ≤ 20</td><td>x > 20</td></tr>
<tr><td>$cgdp$</td><td>W_2</td><td>x > 4</td><td>2 < x ≤ 4</td><td>–2 < x ≤ 2</td><td>–4 < x ≤ –2</td><td>–4 ≥ x</td></tr>
<tr><td>gx</td><td>W_3</td><td>x > 10</td><td>10 ≤ x < 5</td><td>0 < x ≤ 5</td><td>–5 < x ≤ 0</td><td>–5 ≥ x</td></tr>
<tr><td>$debt$</td><td>W_4</td><td></td><td>x ≤ 20</td><td>20 < x ≤ 30</td><td>30 < x ≤ 40</td><td>x > 40</td></tr>
<tr><td>$gdebt$</td><td>W_5</td><td>–10 ≥ x</td><td>–10 < x ≤ 0</td><td>0 < x ≤ 10</td><td>10 < x ≤ 15</td><td>x > 15</td></tr>
<tr><td>$stdebt$</td><td>W_6</td><td></td><td>x ≤ 50</td><td>50 < x ≤ 100</td><td>100 < x ≤ 150</td><td>x > 150</td></tr>
</table>
so that the maximum value of the index equals 10, that is $W_1=W_2=W_3=W_4=W_5=W_6=5/6$</td><td>Quarterly data of 24 developing countries, for the period 1993-1998</td><td>Panel regression</td><td>1. Real exchange rate gap
2. Real interest rates
3. Foreign debt/GDP</td></tr>
<tr><td>4.</td><td>Hattori (2002)</td><td>$I = \%\Delta e - \frac{\sigma_e}{\sigma_r}\%\Delta r$ as the depth of the crisis</td><td>Monthly data of 22 developing countries, for the period 1990-1996</td><td>Cross-section regression</td><td>1. 4-year change of Domestic private credit/GDP ratio
2. Short-term foreign debt/reserves
3. Contagion effect
4. Financial liberalization</td></tr>
</table>

5.	**Won-Am Park (2002)**	*The Exchange market pressure index* $I = \frac{1}{\sigma_e}\Delta e + \frac{1}{\sigma_i}\Delta i - \frac{1}{\sigma_r}\Delta r$ $I > \mu + 1.1 * \sigma_I$ Δi - interest rate change	Monthly data of South Korea, for the period 1990-1997	Signaling approach	1. Terms of trade 2. Asset prices 3. Exports 4. Domestic credit/GDP 5. M2 multiplier
6.	**Eichengr, Rose, Wyplosz (1996)**	$I = \frac{1}{\sigma_e}\%\Delta e + \frac{1}{\sigma_i}\Delta(i - i^*) - \frac{1}{\sigma_r}(\%\Delta r - \%\Delta r^*)$ Non-weighted version is discussed, as well. i^* Ë $\%\Delta r^*$- respectively, change in interest rate and reserves of foreign country (Germany). $I > \mu + 1.5 * \sigma_I$	Quarterly data of 20 developed countries, for the period 1959-1993	Probit method	1. Contagion effect 2. Inflation 3. Unemployment
7.	**Eliasson, Kreuter (2001)**	*Continuous Definition of crisis* Consists of the simple sum of deviations from long-term averages of the *change in exchange rate, changes in the real interest rate* and *the level of real interest rate,* The index is built as a result of the 5-step process: Step 1: Construct the histogram of each indicator. Step 2: Compare the observed distribution with the Gaussian Distribution and get the differences (deviations). Step 3: Compare the distribution of deviations of crisis points (right segment of distribution) with a certain functional form that best describes it. As a result, you will get a distribution function that describes the crises, which is in the (0,1) interval. Step 4: Get functions of 3 variables together. Step 5: The series produced will need to be smoothed out with exponential weighting moving average technique, which smoothens the most remote areas (outlayers) of the series and suggests a gradual transition of the crisis into a peaceful period.	Quarterly data of 10 developing countries, for the period 1990-2000	Multivariate logit model	1. Domestic credit/GDP 2. M2/reserves 3. Short-term debt/Reserves 4. Real interest rate 5. Contagion effect
8.	**Krznar (2004)**	$I = \%\Delta e - \frac{\sigma_e}{\sigma_r}\%\Delta r$ $I > \mu + 2.0 * \sigma_I$	Monthly data of Croatia, for the period 1996-2003	Signaling approach and a Probit method	1. Budget deficit/GDP 2. Current account/GDP 3. Inflation 4. Foreign debt 5. M2 multiplier 6. Real exchange rate deviation from the trend 7. Share of foreign assets in M4 8. Change in domestic credit
9.	**Scherbakov (2000)**	Data from the paper by Kaminsky and others (1998).	Annual data of 13 developing countries, for the period 1970-1999	Probit method	1. M2/Reserves 2. Change in M1/ reserves 3. Decline in real GDP 4. Claims on government /deviation of GDP from the average 5. Short-term debt / deviation of GDP from the average 6. Real exchange rate 7. Openness 8. Bank crises
10.	**Esquivel, Larrain (1998)**	1. $\Delta^3\varepsilon > 15\%$ or 2. $\Delta^1\varepsilon > 2.54\sigma_{\Delta\varepsilon}$ Ë $\Delta^1\varepsilon > 4\%$ $\Delta^3\varepsilon$ - 3-month cumulative change of the real exchange rate $\Delta^1\varepsilon$ - monthly change of the real exchange rate $\sigma_{\Delta\varepsilon}$ - $\Delta^1\varepsilon$ standard deviation	Annual data of 30 developed and developing countries, for the period 1975-1996	Probit method	1. Change in Broad money/ GDP (seigniorage) 2. Real exchange rate gap 3. Reserves/M2 4. Terms of trade 5. Per capita income 6. Contagion effect 7. Current account
11.	**Kaminsky (2003)**	Same way, as Kaminsky and others (1998)	Monthly data of 20 countries, for the period 1970-2001	Regression tree method	1. Real exchange rate overvaluation 2. World interest rates 3. Short-term debt/Reserves 4. Foreign debt/Exports 5. Exports 6. Budget deficit 7. Change in domestic credit/GDP 8. Expansionary monetary policy 9. M2/Reserves
12.	**Racaru, Copaciu, Lapteacru (2006)**	$I = \frac{1}{\sigma_e}\Delta e + \frac{1}{\sigma_i}\Delta i - \frac{1}{\sigma_r}\Delta r$ $I > \mu + 2.0 * \sigma_I$	Monthly data of 26 developing countries, for the period 1994-2004	Signaling approach and a Multivariate Logit method	1. Real exchange rate overvaluation 2. Domestic private credit/GDP 3. Current account/GDP 4. M2/Reserves 5. Export growth rate

13.	**Budsayaplakorn, Dibooglu, Mathur (2006)**	$I = \%\Delta e - \frac{\sigma_e}{\sigma_r}\%\Delta r$ $I > \mu + 2.0 * \sigma_I$	Quarterly data of 5 Asian countries, for the period 1975-1997	Signaling approach and a Multivariate Probit method	1. International reserves 2.Asset prices 3. GDP 4. Domestic credit/GDP 5. Export growth rate
14.	**Schardax (2003)**	At least 20% depreciation of the nominal exchange rate during 10 trading days.	Quarterly data of 12 Eastern and Central European countries, for the period 1992-2002	Signaling approach	1. Change in M2/ gross reserves 2. M2/gross reserves 3. Change in exports 4. Deviation of real exchange rate from the trend 5. Budget deficit/GDP
15.	**Bruggeman, Linne (2002)**	At least 20% depreciation of the nominal exchange rate during 10 trading days.	Monthly data of 5 Eastern and Central European countries, for the period 1993-2001	Signaling approach	1. Export 2. Reserves 3. Credit interest rate /Deposit interest rate 4. Real exchange rate 5. Bank deposits 6. Budget deficit/GDP 7. Industrial production 8. M2 multiplier 9. Domestic credit/GDP 10. Domestic interest rates 11. M2/Reserves 12. Short-term external debt
16.	**Knedlik, Scheufele (2007)**	$I = \frac{1}{\sigma_e}\Delta e + \frac{1}{\sigma_i}\Delta i - \frac{1}{\sigma_r}\Delta r$ $I > \mu + 1.645 * \sigma_I$ 1.645 standard deviation suggests that in case of normal distribution, 5% of the distribution would be crisis-relevant	Monthly data of South Africa countries, for the period 1995-2005	Signaling approach, a Probit method, a Markov-Switching method	1. International liquidity position 2. Change in import of goods 3. Growth rate of Domestic credit/GDP 4. Domestic interest rate 5. Difference between domestic and external interest rates 6. Deposits 7. Growth rate Government's external debt 8. Budget deficit/GDP 9. Growth rate of international gold prices
17.	**Tinakorn (2002)**	3-month cumulative depreciation of the nominal exchange rate > 15% or 3-month cumulative reduction in net international reserves >15%	Monthly data of Thailand, for the period 1992-2000	Signaling approach, a Probit method	1. Change in terms of trade 2. Export growth rate 3. Current account/GDP 4. Real exchange rate gap 5. Short-term debt/Reserves 6. Growth rate of M2/Reserves 7. Growth rate of Domestic credit/GDP 8. Budget deficit/GDP 9. Inflation 10. Real GDP growth rate 11. Change in Asset prices
18.	**Feridun (2006)**	$I = \frac{1}{\sigma_e}\%\Delta e + \frac{1}{\sigma_i}\Delta(i - i^*) - \frac{1}{\sigma_r}(\%\Delta r - \%\Delta r^*)$ $\%\Delta r$ Ë $\%\Delta r^*$ - change in the ratio of reserves to M1of the country and of the foreign country $I > \mu + 1.5 * \sigma_I$	Monthly data of Turkey, for the period 1980-2006	Signaling approach, Paired and Multivariate Probit methods	1. Banking system crises 2. Short-term debt/Reserves 3. GDP of the USA 4. Interest rates of US treasury bills 5. M1
19.	**Goldfaja, Valdes (1997)** Source: **Tinakorn (2002)**	1. Depreciation of the nominal exchange rate > 1.96* exchange rate standard deviation 2. Depreciation of the exchange rate > 2%+1.5* previous month's depreciation 3. $I = \%\Delta e - \frac{\sigma_e}{\sigma_r}\%\Delta r$ $I > \mu + 3.0 * \sigma_I$	Monthly data of 26 countries, for the period 1984-1997	Logit model	1. Overvaluation of the real exchange rate
20.	**Kruger, Osakwe, Page (1998)** Source: **Tinakorn (2002)**	$I = \%\Delta e - \frac{\sigma_e}{\sigma_r}\%\Delta r$ $I > \mu + 1.5 * \sigma_I$	Annual data of 19 countries, for the period 1977-1993	Probit model	1. M2/International reserves 2. Bank claims on private sector/GDP 3. Real exchange rate gap

21.	**Engwatana (1999)** Source: **Tinakorn (2002)**	1. One-month cumulative growth of the nominal exchange rate >10% 2. Monthly deviation of the Forward Premium from its 3-month moving average >10%	Monthly and quarterly data of Thailand, for the period 1990-1998	Probit model	1. Domestic credit 2. M2/International reserves 3. Import coverage 4. Difference between domestic and external interest rates 5. Deviation of the real exchange rate 6. Short-term debt/Reserves 7. Current account deficit
22.	**Poonpatpibul Ittisupornrat (2001)** Source: **Tinakorn (2002)**	3-month cumulative growth of the nominal exchange rate >15%	Monthly data of Thailand, for the period 1990-2000	Signaling approach and a Probit method	1. Export growth rate 2. Change in real exchange rate 3. Terms of trade 4. Loan and deposit interest rates spread 5. M2/Reserves 6. Credit growth rate 7. Inflation
23.	**Milesi-Ferretti, Razin (2000)**	1. Annual depreciation of the nominal exchange rate ≥ 25%, which is more than 10pp higher from the previous year's depreciation: $I_t \geq 25\%$ and $I_t - I_{t-1} \geq 10\%$, where: $I_t = \ln(e_t - e_{t-1})$ e_t - nominal exchange rate 2. $I_t \geq 25\%$ and $I_t - I_{t-1} \geq 100\%$ and $I_{t-1} \leq 40\%$ 3. $I_t \geq 15\%$ and $I_t - I_{t-1} \geq 10\%$ and $I_{t-1} \leq 10\%$ 4. $I_t \geq 15\%$ and $I_t - I_{t-1} \geq 10\%$ and $I_{t-1} \leq 10\%$ and if the exchange rate was fixed a year before the crisis.	Annual data of 105 developing countries, for the period 1975-1996	Multiple Probit	1. International reserves 2. Deviation of the real exchange rate 3. Real US interest rates 4. Economic growth of developed countries 5. Terms of trade 6. Openness of the economy 7. Deficit of current account
24.	**Edison (2003)**	$I = \%\Delta e - \frac{\sigma_e}{\sigma_r}\%\Delta r$ $I > \mu + 2.5 * \sigma_I$ *For one country:* $I > \mu + 1.5 * \sigma_I$	Monthly data of 28 developed and developing countries, for the period 1970-1999	Signaling approach	1. Real exchange rate gap 2. Short-term debt/Reserves 3. International reserves 4. M2/International reserves 5. Export 6. Assets prices 7. Economic growth 8. Excess in M1 9. Economic growth in G-7 countries 10. Real interest rate 11. Credit/GDP
25.	**Abiad (2003)**	Defined endogenously in a Markov-switching model framework	Monthly data of 5 developing countries, for the period 1972-1999	Markov switching model	1. Overvaluation of the real exchange rate 2. M2/International reserves 3. Real GDP growth 4. LIBOR
26	**Nag, Mitra (1999)**	$I = \%\Delta e - \frac{\sigma_e}{\sigma_r}\%\Delta r$ $I > \mu + 2.0 * \sigma_I$	Monthly data of 3 developing countries, for the period 1980-1999	Signaling approach and Neural networks	1. M2/ International reserves 2. International reserves 3. Difference between foreign assets and liabilities 4. Export 5. Money multiplier
27.	**Peltonen (2006)**	$I = \%\Delta e - \frac{\sigma_e}{\sigma_r}\%\Delta r$ $I > \mu + 2.0 * \sigma_I$	Monthly data of 24 developing countries, for the period 1980-2001	Probit Model and Neural Networks	1. Contagion effect 2. De-facto exchange rate regime 3. Current account deficit 4. Budget deficit 5. Real GDP growth
28.	**Ghosh and Ghosh (2002)**	$I = \%\Delta \varepsilon - \frac{\sigma_e}{\sigma_r}\%\Delta r$, where: ε is the real exchange rate $I > \mu + 2.0 * \sigma_I$ and the GDP decline > 3%, 5%	Annual data of 42 developed and developing countries, for the period 1987-1999	Classification tree method and a Probit method	1. Good governance system 2. Current account 3. Real exchange rate 4. Foreign debt/Reserves

Appendix 3: Currency crises (pressures) observed in Armenia, according to various types of exchange market pressure indices

	Version 1	Version 2	Version 3	Version 4	Version 5	Version 6	Version7
Crises	*9**	*8**	*6**	*14**	*11**	*11**	*12**
1/31/1997	1	1	1	1	1	1	1
2/28/1997	1	0	1	1	1	1	1
3/31/1997	1	1	1	1	1	1	1
4/30/1997	1	1	0	1	1	1	1
5/31/1997	1	1	0	1	1	1	1
6/30/1997	1	1	1	0	0	1	0
7/31/1997	0	0	0	0	0	0	0
8/31/1997	0	0	0	0	0	0	0
9/30/1997	0	0	0	0	0	0	0
10/31/1997	0	0	0	1	0	0	0
11/30/1997	1	1	0	1	1	1	1
12/31/1997	0	0	0	0	0	0	0
1/31/1998	0	0	0	0	0	0	0
2/28/1998	0	1	0	1	0	0	0
3/31/1998	0	0	0	0	0	0	0
4/30/1998	0	0	0	0	0	0	0
5/31/1998	0	0	0	0	0	0	0
6/30/1998	0	0	0	0	0	0	0
7/31/1998	1	1	0	1	1	1	1
8/31/1998	0	0	0	0	0	0	1
9/30/1998	0	0	0	0	0	0	0
10/31/1998	0	0	0	0	0	0	0
11/30/1998	1	0	0	1	1	1	0
12/31/1998	0	0	0	0	0	0	0
1/31/1999	0	0	1	1	1	1	1
2/28/1999	0	0	0	0	0	0	0
3/31/1999	0	0	0	0	0	0	0
4/30/1999	0	0	0	1	1	1	1
5/31/1999	0	0	0	0	0	0	0
6/30/1999	0	0	0	0	0	0	0
7/31/1999	0	0	0	0	0	0	0
8/31/1999	0	0	0	0	0	0	0
9/30/1999	0	0	0	0	0	0	0
10/31/1999	0	0	0	1	0	0	0
11/30/1999	0	0	0	0	0	0	0
12/31/1999	0	0	0	0	0	0	0
1/31/2000	0	0	0	0	0	0	0
2/29/2000	0	0	0	0	0	0	0
3/31/2000	0	0	0	0	0	0	0
4/30/2000	0	0	0	0	0	0	0
5/31/2000	0	0	0	0	0	0	0
6/30/2000	0	0	0	0	0	0	0
7/31/2000	0	0	0	0	0	0	0
8/31/2000	0	0	0	0	0	0	0
9/30/2000	0	0	0	0	0	0	0
10/31/2000	0	0	0	0	0	0	0
11/30/2000	0	0	0	0	0	0	0
12/31/2000	0	0	0	0	0	0	0
1/31/2001	0	0	0	1	1	0	1
2/28/2001	0	0	0	0	0	0	0
3/31/2001	0	0	0	0	0	0	0
4/30/2001	0	0	0	0	0	0	0
5/31/2001	0	0	0	0	0	0	0
6/30/2001	0	0	0	0	0	0	0
7/31/2001	0	0	0	0	0	0	0
8/31/2001	0	0	0	0	0	0	0
9/30/2001	0	0	0	0	0	0	0
10/31/2001	0	0	0	0	0	0	0
11/30/2001	0	0	0	0	0	0	0
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1/31/2002	0	0	0	0	0	0	0
2/28/2002	0	0	0	0	0	0	0
3/31/2002	0	0	0	0	0	0	0
4/30/2002	0	0	0	0	0	0	1
5/31/2002	0	0	0	0	0	0	0
6/30/2002	0	0	0	0	0	0	0
7/31/2002	0	0	0	0	0	0	0
8/31/2002	0	0	0	0	0	0	0
9/30/2002	0	0	0	0	0	0	0
10/31/2002	0	0	0	0	0	0	0
11/30/2002	0	0	0	0	0	0	0
12/31/2002	0	0	0	0	0	0	0
1/31/2003	0	0	0	0	0	0	0
2/28/2003	0	0	0	0	0	0	0
3/31/2003	0	0	0	0	0	0	0

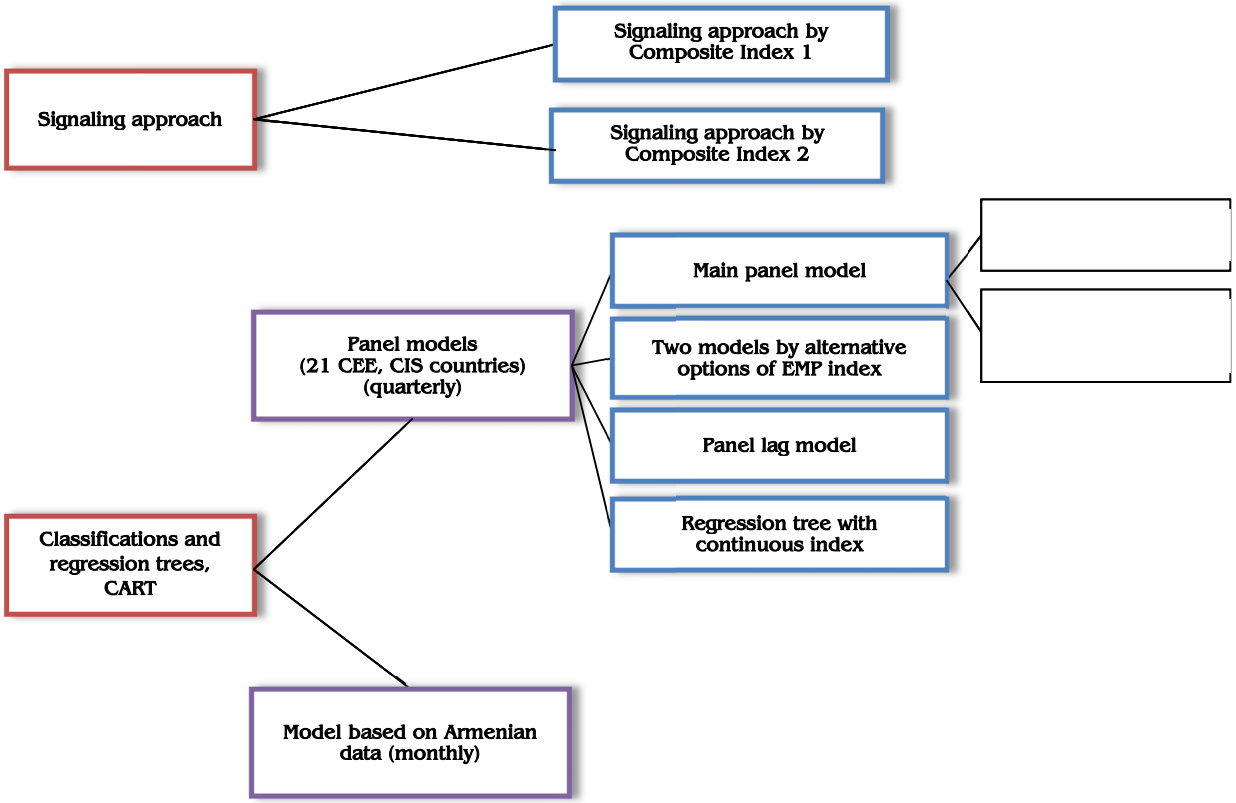
4/30/2003	0	0	0	0	0	0	0
5/31/2003	0	0	0	0	0	0	0
6/30/2003	0	0	0	0	0	0	0
7/31/2003	0	0	0	0	0	0	0
8/31/2003	0	0	0	0	0	0	0
9/30/2003	0	0	0	0	0	0	0
10/31/2003	0	0	0	0	0	0	0
11/30/2003	0	0	0	0	0	0	0
12/31/2003	0	0	0	0	0	0	0
1/31/2004	0	0	0	0	0	0	0
2/29/2004	0	0	0	0	0	0	0
3/31/2004	0	0	0	0	0	0	0
4/30/2004	0	0	0	0	0	0	0
5/31/2004	0	0	0	0	0	0	0
6/30/2004	0	0	0	0	0	0	0
7/31/2004	0	0	0	0	0	0	0
8/31/2004	0	0	0	0	0	0	0
9/30/2004	0	0	0	0	0	0	0
10/31/2004	0	0	0	0	0	0	0
11/30/2004	0	0	0	0	0	0	0
12/31/2004	0	0	0	0	0	0	0
1/31/2005	0	0	0	0	0	0	0
2/28/2005	0	0	0	0	0	0	0
3/31/2005	0	0	0	0	0	0	0
4/30/2005	0	0	0	0	0	0	0
5/31/2005	0	0	0	0	0	0	0
6/30/2005	0	0	0	0	0	0	0
7/31/2005	0	0	0	0	0	0	0
8/31/2005	0	0	1	0	0	0	0
9/30/2005	0	0	0	0	0	0	0
10/31/2005	0	0	0	0	0	0	0
11/30/2005	0	0	0	0	0	0	0
12/31/2005	0	0	0	0	0	0	0
1/31/2006	0	0	0	0	0	0	0
2/28/2006	0	0	0	0	0	0	0
3/31/2006	0	0	0	0	0	0	0
4/30/2006	0	0	0	0	0	0	0
5/31/2006	0	0	0	0	0	0	0
6/30/2006	0	0	0	0	0	0	0
7/31/2006	0	0	0	0	0	0	0
8/31/2006	0	0	0	0	0	0	0
9/30/2006	0	0	0	0	0	0	0
10/31/2006	0	0	0	0	0	0	0
11/30/2006	0	0	0	0	0	0	0
12/31/2006	0	0	0	0	0	0	0
1/31/2007	0	0	0	0	0	0	0
2/28/2007	0	0	0	0	0	0	0
3/31/2007	0	0	0	0	0	0	0
4/30/2007	0	0	0	0	0	0	0
5/31/2007	0	0	0	0	0	0	0
6/30/2007	0	0	0	0	0	0	0
7/31/2007	0	0	0	0	0	0	0
8/31/2007	0	0	0	0	0	0	0
9/30/2007	0	0	0	0	0	0	0
10/31/2007	0	0	0	0	0	0	0
11/30/2007	0	0	0	0	0	0	0
12/31/2007	0	0	0	0	0	0	0
1/31/2008	0	0	0	0	0	0	0
2/29/2008	0	0	0	0	0	0	0
3/31/2008	0	0	0	0	0	0	0
4/30/2008	0	0	0	0	0	0	0
5/31/2008	0	0	0	0	0	0	0
6/30/2008	0	0	0	0	0	0	0
7/31/2008	0	0	0	0	0	0	0
8/31/2008	0	0	0	0	0	0	0
9/30/2008	0	0	0	0	0	0	0
10/31/2008	0	0	0	0	0	0	0
11/30/2008	0	0	0	0	0	0	0
12/31/2008	0	0	0	0	0	0	0
1/31/2009	0	0	0	1	0	0	0
2/28/2009	0	0	1	1	0	0	0
3/31/2009	1	1	1	1	1	1	1
4/30/2009	0	1	1	1	1	1	1
5/31/2009	0	0	0	0	0	0	0
6/30/2009	0	0	0	0	0	0	0
7/31/2009	0	0	0	0	0	0	0
8/31/2009	0	0	0	0	0	1	0
9/30/2009							

** Number of the crises (pressures) observed up to December of 2008.*

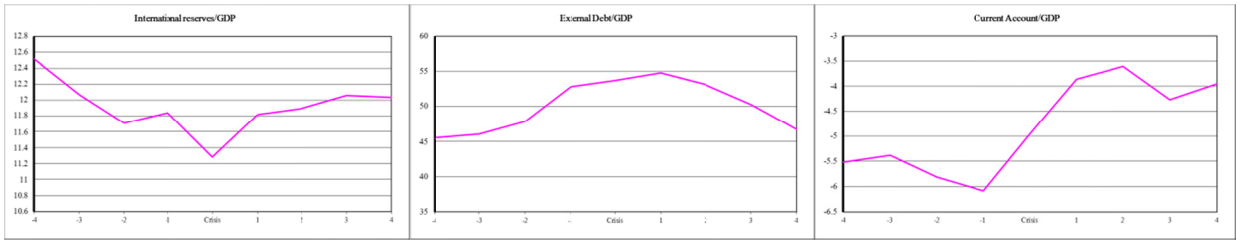
Appendix 4: The Main leading indicators discussed in different papers

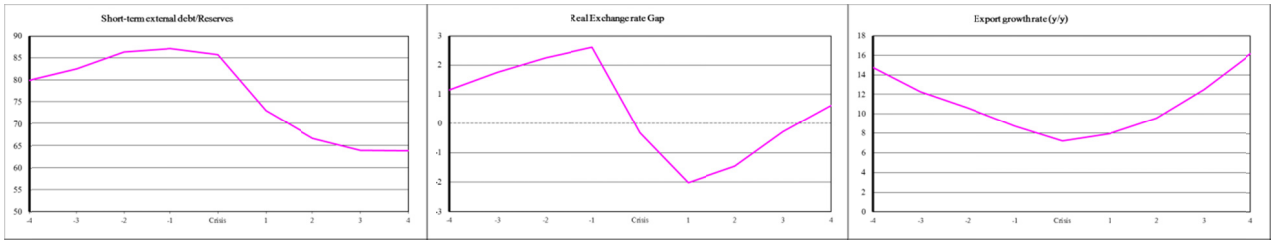
Indicator	Kaminsky, Lizondo, Reinhart (1998) – the results of 28 papers	Hawkins, Klau (2000) – the results of 34 papers of financial crises for 1998-2000, 27 of which related to currency crises	Abiad (2003) – the results of those 6 works out of 34, which were not reviewed in the previous two papers	The results of 25 papers reviewed which were not discussed in the previous ones	A total of 86 papers	Appearance rate, (%)	Rank
Real exchange rate	12	23	5	16	56	65.12	1
International reserves	11	23	1	9	44	51.16	2
M2/International reserves	3	15	3	15	36	41.86	3
Credit growth	5	9	4	15	33	38.37	4
Current account	2	15	5	6	28	32.56	5
Exports	2	9	1	12	24	27.91	6
Real GDP growth rate or level	5	11		8	24	27.91	6
Budget deficit	3	6	2	7	18	20.93	8
Inflation	5	7	1	4	17	19.77	9
Short-term external debt/Reserves			3	11	14	16.28	10
Change in asset prices	1	7		6	14	16.28	10
Terms of trade	2	6		5	13	15.12	12
Real interest rate	1	5		6	12	13.95	13
Crisis in the region, contagion effect	1	7		4	12	13.95	13
Foreign debt	0	5	2	4	11	12.79	15
Foreign interest rate	2		1	4	7	8.14	16
Money multiplier	1			5	6	6.98	17
Trade account	2		1	1	4	4.65	18
Real GDP growth of foreign country	1			3	4	4.65	18
Broad money	2			2	4	4.65	18
Credit to public sector	3			1	4	4.65	18
Banking system crisis	1			3	4	4.65	18
Current government wins or government loses in elections	1	3			4	4.65	18
Money supply/Demand gap	1			2	3	3.49	24
Difference between domestic and foreign interest rates			1	2	3	3.49	24
Employment/unemployment	2		1		3	3.49	24
Openness of the economy	1			2	3	3.49	24
Import coverage				2	2	2.33	28
Foreign direct investment	2				2	2.33	28
Import	1			1	2	2.33	28
Loans and deposits interest rates spread				2	2	2.33	28
Change in bank deposits	0			2	2	2.33	28
Output gap	1			1	2	2.33	28
Exchange rate regime			1	1	2	2.33	28
Financial liberalization	1			1	2	2.33	28
Public debt	0			1	1	1.16	36

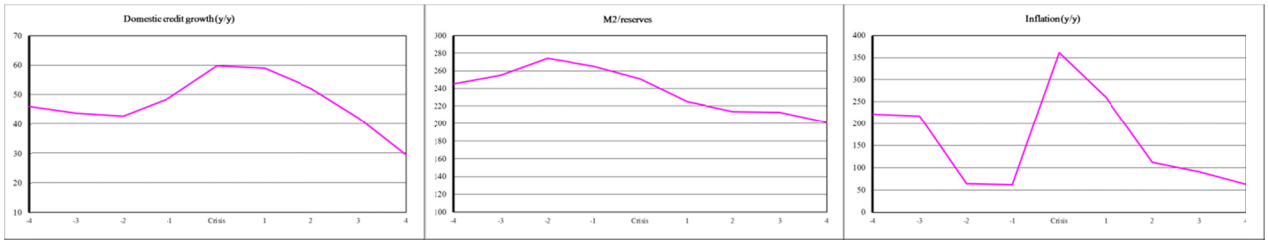
Appendix 5: EWS in Armenia

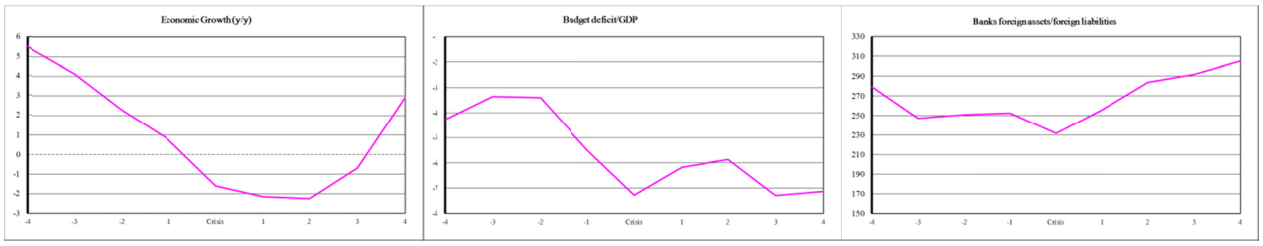


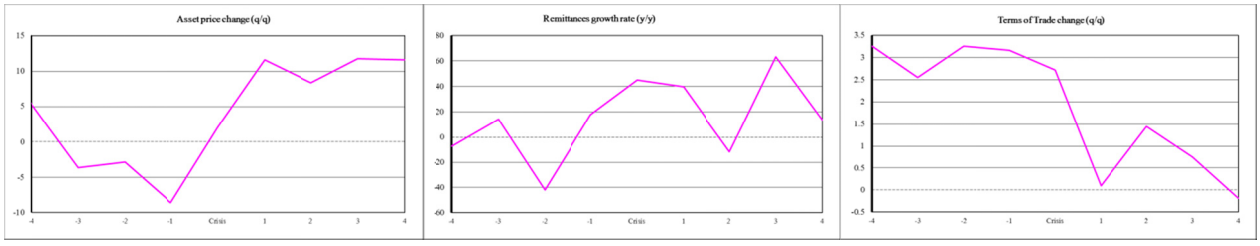
Appendix 6-A: Graphical presentation of the pre-crisis and post-crisis movement of leading indicators (Panel version)

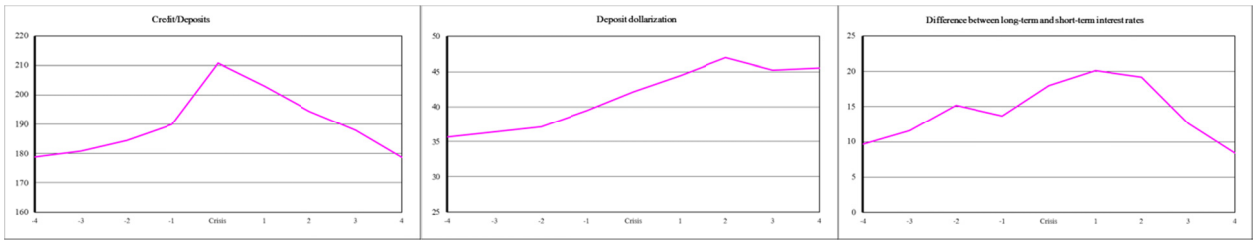




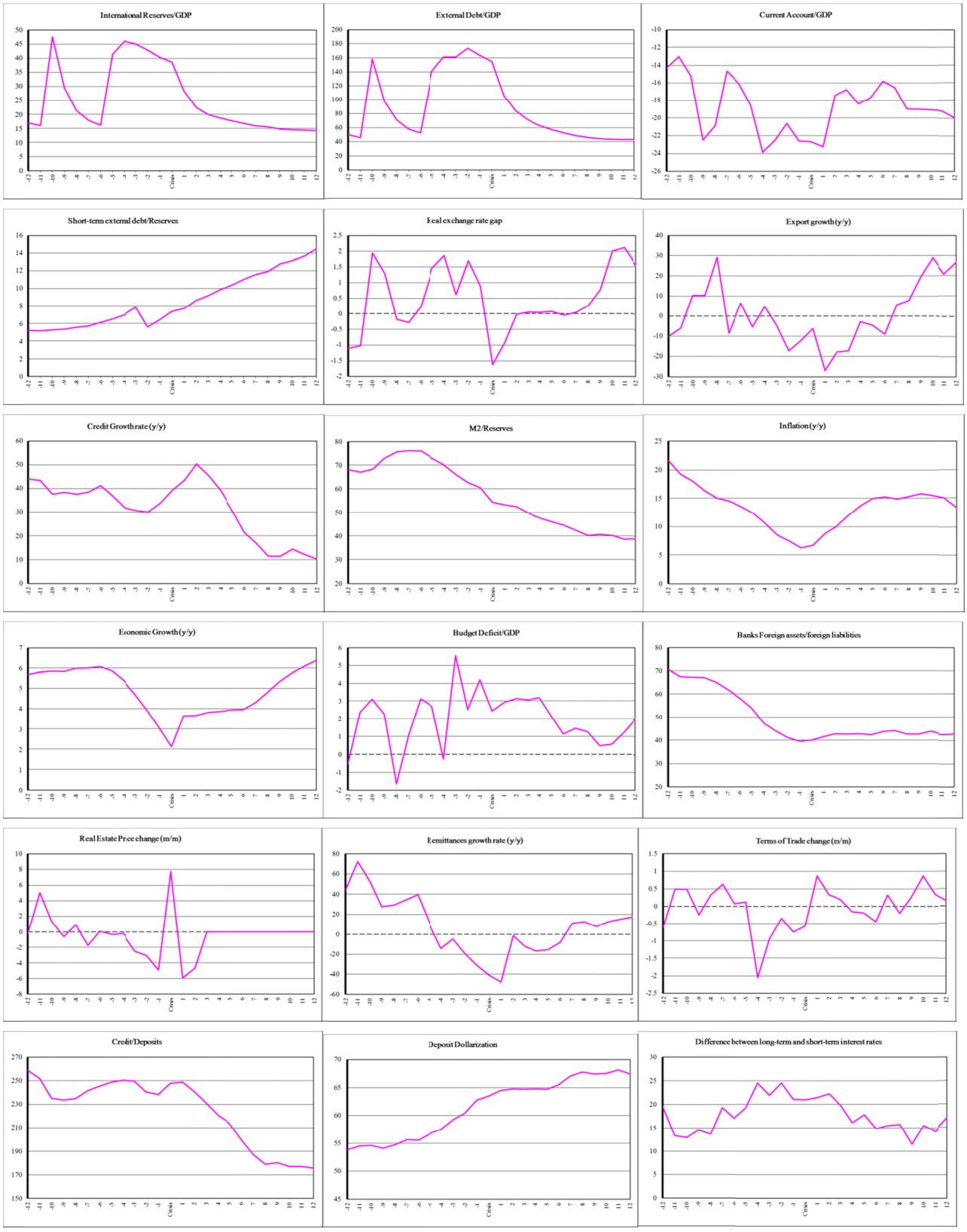








Appendix 6-B: Graphical presentation of the pre-crisis and post-crisis movement of leading indicators (Case of Armenia)



Appendix 7: Signaling approach: An alternative model results

This alternative model of signaling approach was built under the following assumption:

- A grid of reference percentiles of 10%-35% and 65%-90%,
- Composite index does not include the variables with noise-to-signal ratios above 1.

In this option the leading indicators have produced more diversified results in terms of distribution of noise-to-signal ratios (see Table A7-1). Most of the indicators, with the exception of those of short-term foreign debt and dollarization, proved to have contained good forecasting characteristics in the primary model as well. It should be noted that some changes have taken place in the comparative advantages of indicators, although here, as in the primary model, the best ones are inflation and lending/deposit indicators. In this model, however, indicators such as real estate prices[79], the banks' foreign assets/liabilities as well as export and current account variables are gaining importance.

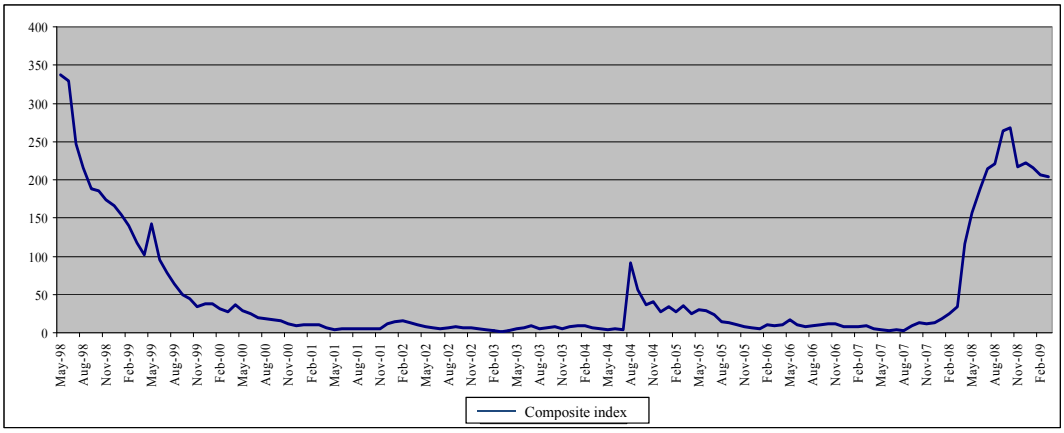
Table A7-1: Leading indicators by relevance (Alternative)

	Absolute thresholds	Relative thresholds (percentile)	Noise to signal ratio	Conditional probability* %	Called crises** %	Rank
Export growth rate	-19.92	0.10	0.10	76.47	100	5
Real exchange rate overvaluation	3.10	0.86	0.47	39.13	90	16
M2/International reserves	99.65	0.89	0.22	65.00	70	9
Real estate price growth rate	-0.06	0.12	0.08	66.67	10	3
Current account/GDP	-19.94	0.13	0.11	73.68	90	6
Budget deficit/GDP	-0.89	0.20	0.95	24.14	30	18
Short-term foreign debt/International reserves	10.89	0.20	2.26	14.52	30	19
Domestic credit growth rate	68.60	0.89	0.26	61.11	30	11
Foreign debt/GDP	63.00	0.89	0.29	50.00	70	12
Inflation	9.57	0.80	0.01	96.77	100	1
Economic growth	4.06	0.15	0.30	57.69	90	13
Remittances growth rate	-7.71	0.12	0.31	38.89	20	14
Banks' foreign assets/foreign liabilities	46.29	0.22	0.10	81.08	100	4
Terms of trade	-2.03	0.13	0.44	40.00	40	15
Credit/Deposits	193.61	0.86	0.02	95.45	90	2
International oil prices	20.14	0.25	0.18	69.23	90	7
Difference between long-term and short-term interest rates	22.70	0.88	0.19	68.42	90	8
Global economic growth	-1.66	0.10	0.65	38.89	10	17
Dollarization	71.98	0.67	20.95	1.92	20	20
International reserves/GDP	13.41	0.11	0.243	55.556	10	10

** Denotes the probability of emergence of the crisis, provided that the indicator has signaled A/(A+B).*
*** Denotes part of crises that a particular indicator has called.*

Despite the differences in the results in terms of relevance of leading indicators and forecasting characteristics, the Composite Indices trended through similar paths and outcome.

Figure A7-1: Composite index dynamics (Alternative)



[79] *Some caution needs to be exercised with respect of the results of real estate price indicator as it has been only able to respond to the March 2009 devaluation due to shortness in time series.*

Table A7-2: Conditional probability of the crisis by Composite Index value (Alternative)

Composite Index	Conditional probability (%)
0-33.66	0
33.66-155.80	9.52
155.80 and over	94.3
Unconditional probability	**6.8**

In this model, the value of 155.8 can be considered the threshold for the Composite Index; values coming above that may mean the probability of the crisis would exceed the 50% level.

Figure A7-2: Composite Index dynamics (instant approach) (Alternative)

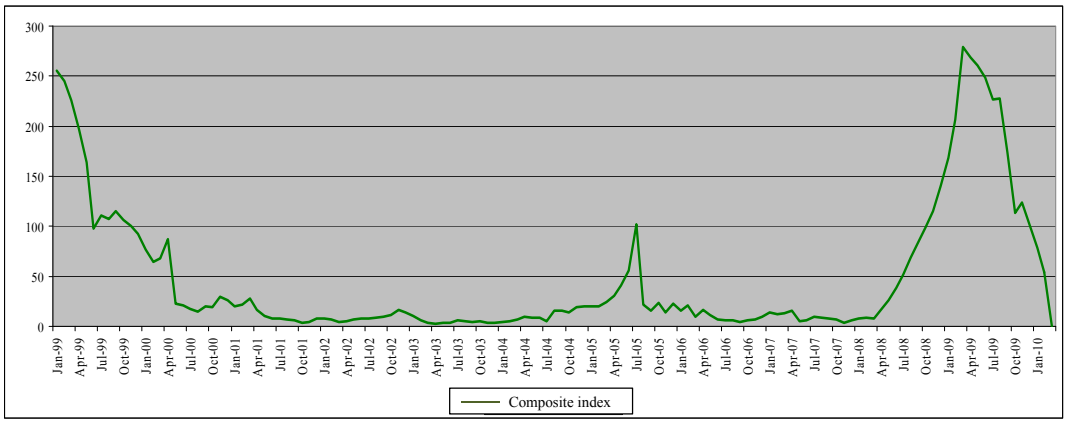


Table A7-3: Conditional probability of crisis by Composite Index value (instant approach) (Alternative)

Composite Index	Conditional probability (%)
0 – 272.60	0
272.60- 378.22	18.75
378.22 and over	87.5
Unconditional probability	**6.8**

Three of the crises registered occurred when the index was in the range of 272.6-378.22 range, and the remaining 7, in the range with more than 378.22 of value, and therefore an index value of 378.22 can be regarded as the threshold level. Let's just say that in March of 2009 the combined index value was 279.25, which is only about 20% probability of a crisis.

Appendix 8-A[80]: Results of the main panel CART model

The following basic rules and restrictions were used in building the classifications tree:

1. The Gini criterion was used as a splitting-rule, which provides the smallest relative error compared to the other rules:

Table A8-A-1[81]: RULE Battery sensitivity test results

Model Name	1SE Terminal Nodes	Rel. Error	SplittingRule
Tree 1	37	0.3994	Sym Gini
Tree 2	37	0.3994	Gini
Tree 3	21	0.4168	Twoing
Tree 4	15	0.4189	Ord. Twoing
Tree 5	9	0.4390	Entropy
Tree 6	19	0.6707	Cl. Prob

2. Equal priors option was used in the class assignment process (the sensitivity test results are the best).

3. The predictive accuracy of trees was assessed by 5-fold cross-validation method (best by the sensitivity test results: *Table A8-A-2*).

Table A8-A-2: CV Battery sensitivity test results

Model Name	1SE Terminal Nodes	Rel. Error	CV Fold
Tree 1	37	0.3994	5
Tree 2	39	0.4316	10
Tree 3	16	0.4373	20
Tree 4	16	0.4362	50

4. The following restrictions were set: the minimum number of observations in parent nodes, 10, the maximum depth of the model 17, the minimum size of the terminal node, 2 observations (one of the bests by the sensitivity test).

5. Since there are a number of high-level categorical variables (elections, democracy) in the model, a penalty coefficient of 1 (Categorical Penalty for High Level=1) was used to get their diverse influences limited.

The estimated model is characterized by the following results:

1. The data contain 1222 observations, of which 302 (24.71%) are crisis situations:

Class	Learn	%	Total
0	920	75.29	920
1	302	24.71	302
Total:	1222	100.00	1222

2. The classifications tree with the smallest misclassification cost according to the Cost-Complexity equation consists of 58 terminal nodes while the best tree selected through the 1 SD rule consists of 37 terminal nodes *(see Table P8-A-3)*, which provides the description of currency crises by the use of 24 variables[82].

[80] *Apart from diverse estimation result presented, other indicators or statistics are also possible to get, which is a matter of separate analyses.*
[81] *Because, in other appendices of the paper, the results of the models will be presented without comments, all the tables are presented in the form as the software gives.*
[82] *From now and on, all the results are pertinent to the best tree selected through the 1 SD rule.*

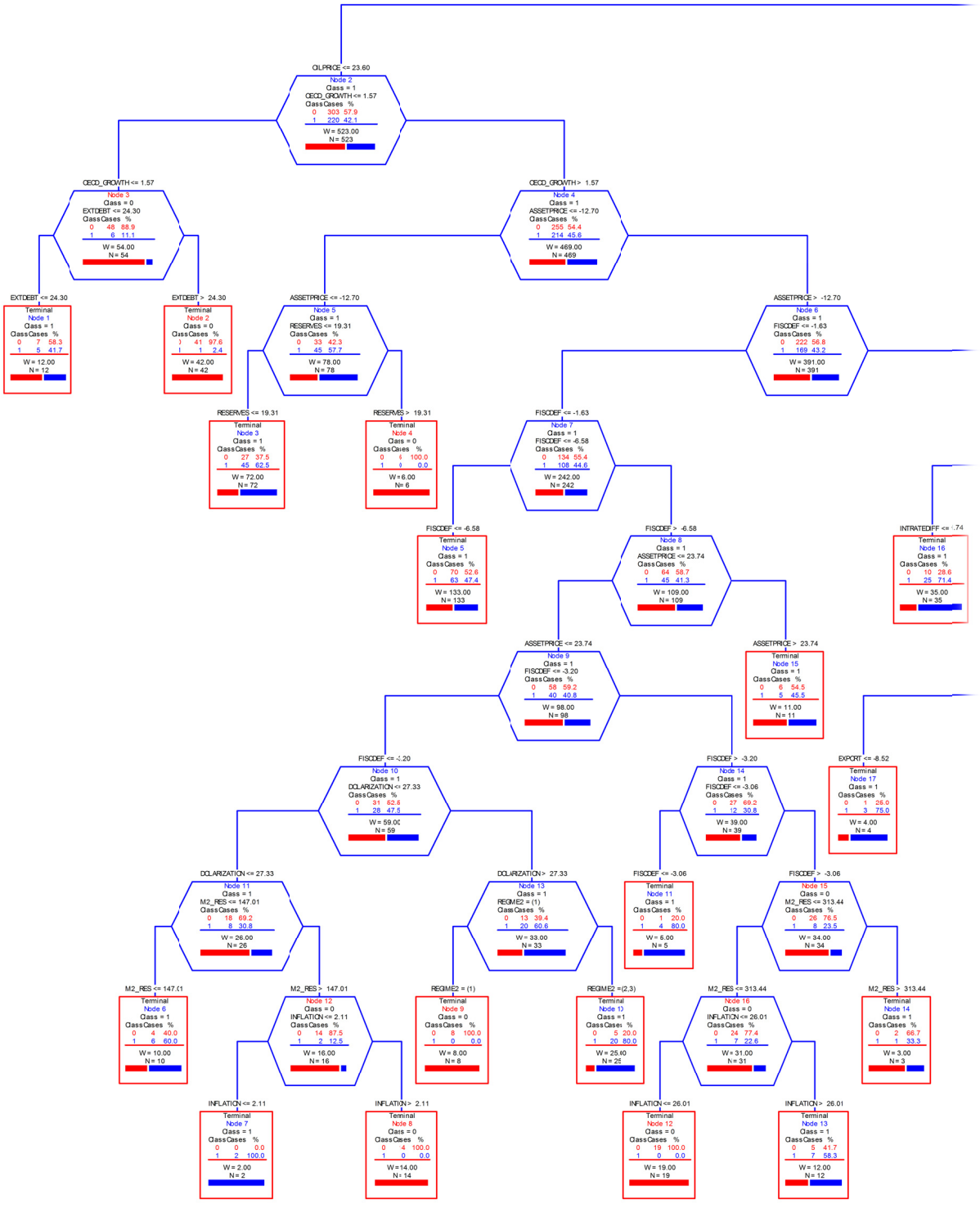
Table A8-A-3: Set of nested and pruned trees

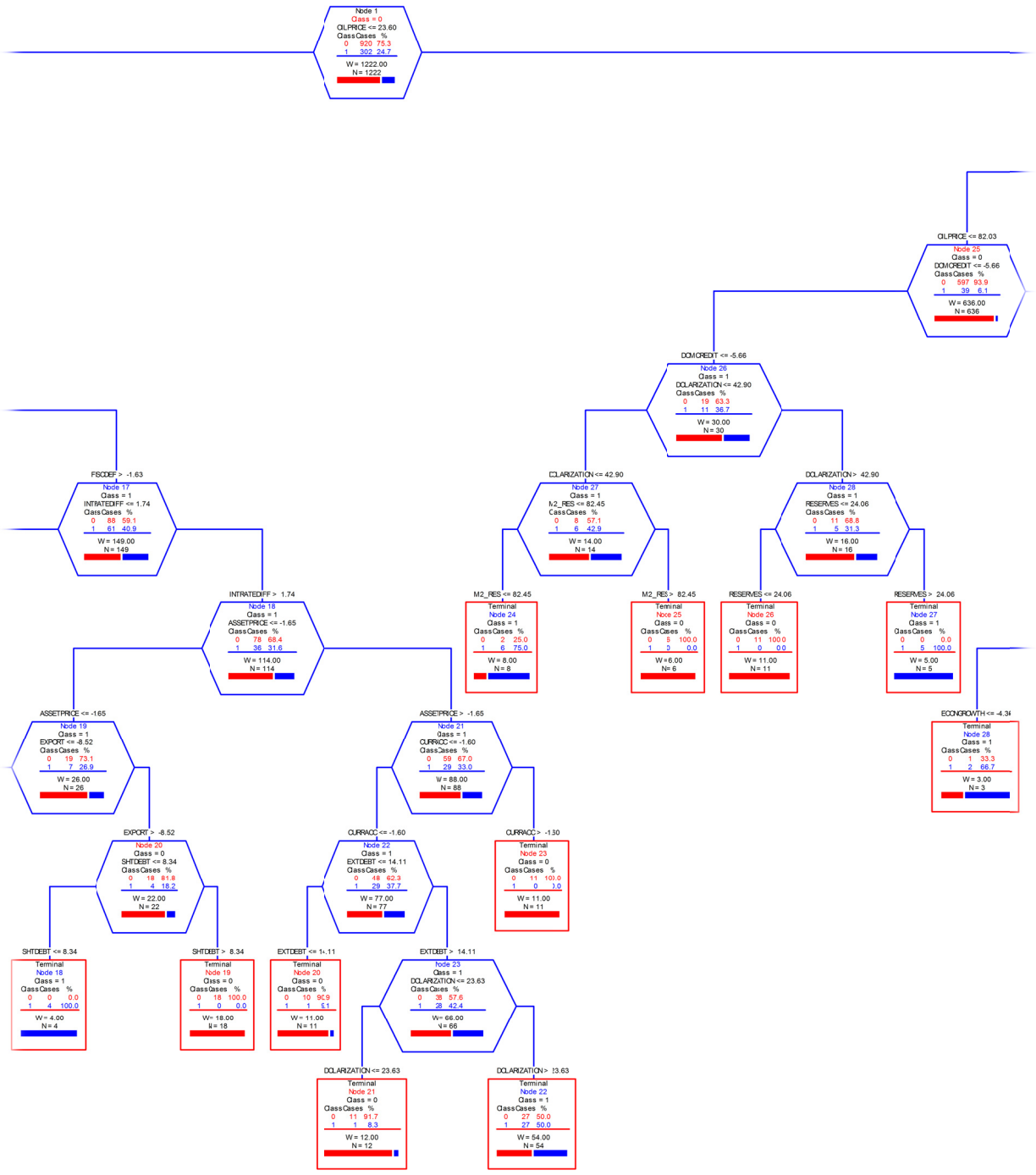
Tree Num.	Terminal Nodes	Cross-Validated Relative Cost	Resubstitution Relative Cost	Complexity
1	95	0.43209 ± 0.02801	0.10263	0.00000
2	92	0.43100 ± 0.02799	0.10263	1.00000E-005
3	91	0.43861 ± 0.02809	0.10361	0.00050
4	83	0.43861 ± 0.02809	0.11231	0.00055
5	81	0.43085 ± 0.02781	0.11453	0.00057
6	80	0.40644 ± 0.02682	0.11666	0.00107
7	75	0.40644 ± 0.02682	0.12753	0.00110
8	70	0.39868 ± 0.02648	0.13865	0.00112
9	60	0.40194 ± 0.02652	0.16468	0.00131
10*	58	0.38523 ± 0.02558	0.17007	0.00136
11	54	0.40075 ± 0.02633	0.18094	0.00137
12	51	0.40075 + 0.02633	0.18979	0.00148
13	48	0.40075 ± 0.02633	0.19947	0.00162
14	45	0.40075 ± 0.02633	0.20925	0.00164
15	39	0.40292 ± 0.02636	0.23099	0.00182
16**	37	0.39941 ± 0.02585	0.23968	0.00218
17	27	0.41364 ± 0.02620	0.28425	0.00224
18	26	0.42125 ± 0.02629	0.28963	0.00270
19	16	0.41784 ± 0.02595	0.34388	0.00272
20	15	0.41784 ± 0.02595	0.34942	0.00278
21	13	0.42871 ± 0.02606	0.36163	0.00306
22	10	0.42866 ± 0.02596	0.38010	0.00309
23	9	0.43627 ± 0.02603	0.38673	0.00332
24	8	0.42846 ± 0.02551	0.39433	0.00381
25	7	0.46728 ± 0.02509	0.40328	0.00448
26	6	0.47009 ± 0.02378	0.41731	0.00702
27	5	0.47009 ± 0.02378	0.43215	0.00743
28	4	0.47603 + 0.02528	0.44792	0.00790
29	3	0.48778 ± 0.02480	0.48023	0.01616
30	2	0.60087 ± 0.02992	0.60087	0.06033
31	1	1.00000 ± 0.00009	1.00000	0.19957

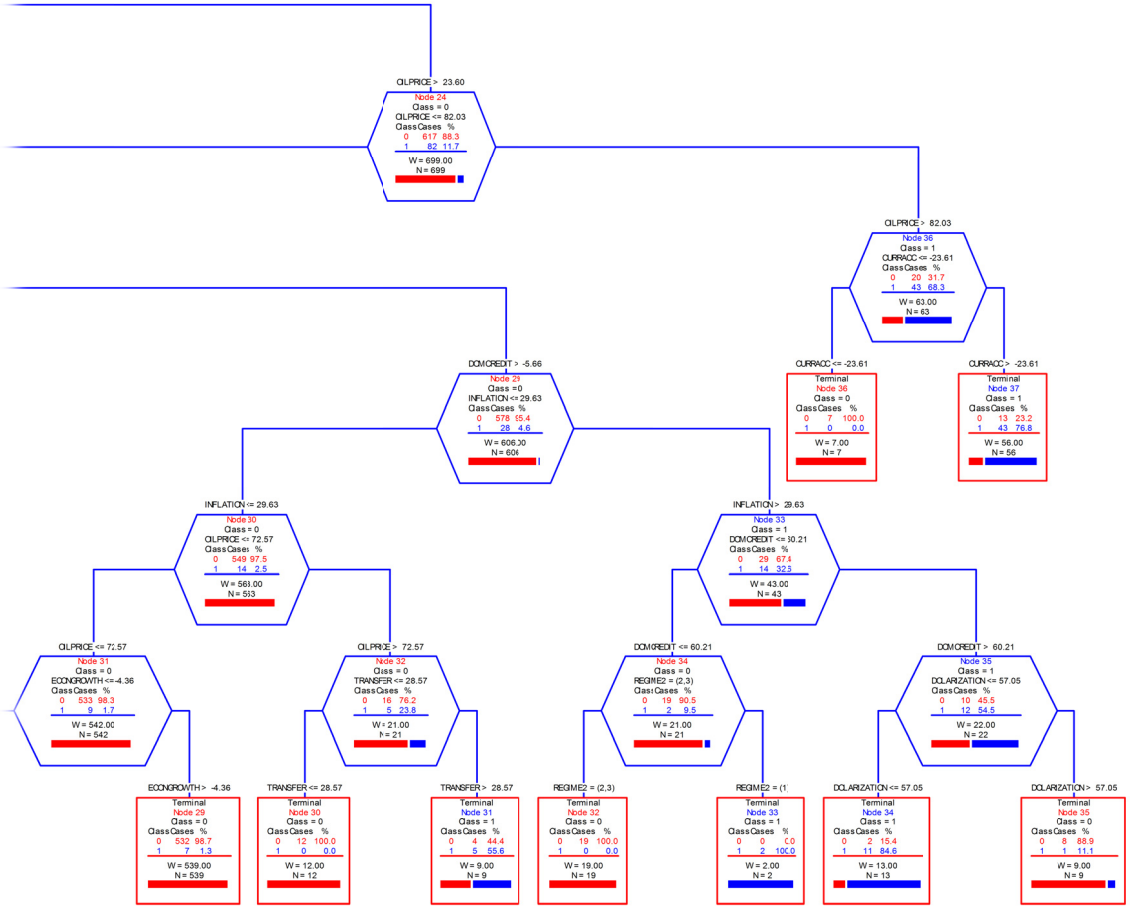
** A tree with the smallest costs*

*** Optimal tree*

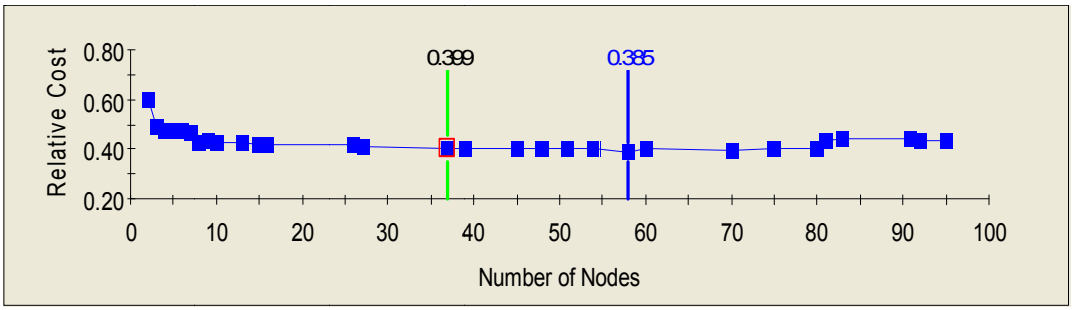
3. General topology of the tree




Node 1
Class = 0
OILPRICE <= 23.60
Class Cases %
0 920 75.3
1 302 24.7
W = 1222.00
N = 1222
OILPRICE <= 82.03
Node 25
Class = 0
DOMCREDIT <= -5.66
Class Cases %
0 597 93.9
1 39 6.1
W = 636.00
N = 636
DOMCREDIT <= -5.66
Node 26
Class = 1
DOLARIZATION <= 42.90
Class Cases %
0 19 63.3
1 11 36.7
W = 30.00
N = 30
FSCDEF > -1.63
Node 17
Class = 1
INTRATEDIFF <= 1.74
Class Cases %
0 88 59.1
1 61 40.9
W = 149.00
N = 149
DOLARIZATION <= 42.90
Node 27
Class = 1
M2_RES <= 82.45
Class Cases %
0 8 57.1
1 6 42.9
W = 14.00
N = 14
DOLARIZATION > 42.90
Node 28
Class = 1
RESERVES <= 24.06
Class Cases %
0 11 68.8
1 5 31.3
W = 16.00
N = 16
INTRATEDIFF > 1.74
Node 18
Class = 1
ASSETPRICE <= -1.65
Class Cases %
0 78 68.4
1 36 31.6
W = 114.00
N = 114
M2_RES <= 82.45
Terminal
Node 24
Class = 1
Class Cases %
0 2 25.0
1 6 75.0
W = 8.00
N = 8
M2_RES > 82.45
Terminal
Node 25
Class = 0
Class Cases %
0 6 100.0
1 0 0.0
W = 6.00
N = 6
RESERVES <= 24.06
Terminal
Node 26
Class = 0
Class Cases %
0 11 100.0
1 0 0.0
W = 11.00
N = 11
RESERVES > 24.06
Terminal
Node 27
Class = 1
Class Cases %
0 0 0.0
1 5 100.0
W = 5.00
N = 5
ASSETPRICE <= -1.65
Node 19
Class = 1
EXPORT <= -8.52
Class Cases %
0 19 73.1
1 7 26.9
W = 26.00
N = 26
ASSETPRICE > -1.65
Node 21
Class = 1
CURRACC <= -1.60
Class Cases %
0 59 67.0
1 29 33.0
W = 88.00
N = 88
ECONGROWTH <= -4.34
Terminal
Node 28
Class = 1
Class Cases %
0 1 33.3
1 2 66.7
W = 3.00
N = 3
EXPORT > -8.52
Node 20
Class = 0
SHTDEBT <= 8.34
Class Cases %
0 18 81.8
1 4 18.2
W = 22.00
N = 22
CURRACC <= -1.60
Node 22
Class = 1
EXTDEBT <= 14.11
Class Cases %
0 48 62.3
1 29 37.7
W = 77.00
N = 77
CURRACC > -1.60
Terminal
Node 23
Class = 0
Class Cases %
0 11 100.0
1 0 0.0
W = 11.00
N = 11
SHTDEBT <= 8.34
Terminal
Node 18
Class = 1
Class Cases %
0 0 0.0
1 4 100.0
W = 4.00
N = 4
SHTDEBT > 8.34
Terminal
Node 19
Class = 0
Class Cases %
0 18 100.0
1 0 0.0
W = 18.00
N = 18
EXTDEBT <= 14.11
Terminal
Node 20
Class = 0
Class Cases %
0 10 90.9
1 1 9.1
W = 11.00
N = 11
EXTDEBT > 14.11
Node 23
Class = 1
DOLARIZATION <= 23.63
Class Cases %
0 38 57.6
1 28 42.4
W = 66.00
N = 66
DOLARIZATION <= 23.63
Terminal
Node 21
Class = 0
Class Cases %
0 11 91.7
1 1 8.3
W = 12.00
N = 12
DOLARIZATION > 23.63
Terminal
Node 22
Class = 1
Class Cases %
0 27 50.0
1 27 50.0
W = 54.00
N = 54



4. The relative error or cost of the model is 0.399; this indicator is usually within the (0,1) interval. The value 0 corresponds to the ideal fit model, and the value 1 pertains to the random selection model. Values above 1 are also possible in case the model has not as good properties as a random walk model.



5. Among key indicators that describe the properties of the model is criterion ROC, which represents the relative proportion of observations classified to be right or wrong as a result of cross-validations. That said, this may also provide an understanding of the sensitivity of the results in response to negligible change in sampling. This can be compared with R^2 coefficient of the regression analysis. The criterion ROC accepts values from the range (0,1) – the bigger, the better. Our model has got excellent results:

   ROC Train=0.9185, ROC Test=0.8227:

6. The extent to which each node has a contribution in the tree for evaluation of the crisis episodes (we may have it also obtained for a non-crisis class) is presented through a Gains Chart and Table, as follows:

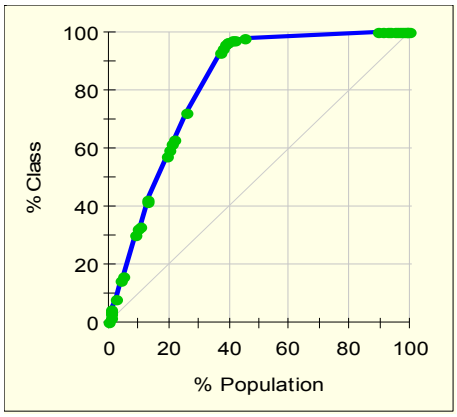


Table A8-A-4: The Gains table for the crisis class

Node	Cases Tgt. Class	% of Node Tgt. Class	% Tgt. Class	Cum % Tgt. Class	Cum % Pop	% Pop	Cases in Node	Cum lift	Lift Pop
27	5	100.00	1.66	1.66	0.41	0.41	5	4.05	4.05
18	4	100.00	1.32	2.98	0.74	0.33	4	4.05	4.05
7	2	100.00	0.66	3.64	0.90	0.16	2	4.05	4.05
33	2	100.00	0.66	4.30	1.06	0.16	2	4.05	4.05
34	11	84.62	3.64	7.95	2.13	1.06	13	3.74	3.42
10	20	80.00	6.62	14.57	4.17	2.05	25	3.49	3.24
11	4	80.00	1.32	15.89	4.58	0.41	5	3.47	3.24
37	43	76.79	14.24	30.13	9.17	4.58	56	3.29	3.11
24	6	75.00	1.99	32.12	9.82	0.65	8	3.27	3.03
17	3	75.00	0.99	33.11	10.15	0.33	4	3.26	3.03
16	25	71.43	8.28	41.39	13.01	2.86	35	3.18	2.89
28	2	66.67	0.66	42.05	13.26	0.25	3	3.17	2.70
3	45	62.50	14.90	56.95	19.15	5.89	72	2.97	2.53
6	6	60.00	1.99	58.94	19.97	0.82	10	2.95	2.43
13	7	58.33	2.32	61.26	20.95	0.98	12	2.92	2.36
31	5	55.56	1.66	62.91	21.69	0.74	9	2.90	2.25
22	27	50.00	8.94	71.85	26.10	4.42	54	2.75	2.02
5	63	47.37	20.86	92.72	36.99	10.88	133	2.51	1.92
15	5	45.45	1.66	94.37	37.89	0.90	11	2.49	1.84
1	5	41.67	1.66	96.03	38.87	0.98	12	2.47	1.69
14	1	33.33	0.33	96.36	39.12	0.25	3	2.46	1.35
35	1	11.11	0.33	96.69	39.85	0.74	9	2.43	0.45
20	1	9.09	0.33	97.02	40.75	0.90	11	2.38	0.37
21	1	8.33	0.33	97.35	41.73	0.98	12	2.33	0.34
2	1	2.38	0.33	97.68	45.17	3.44	42	2.16	0.10
29	7	1.30	2.32	100.00	89.28	44.11	539	1.12	0.05
12	0	0.00	0.00	100.00	90.83	1.55	19	1.10	0.00
32	0	0.00	0.00	100.00	92.39	1.55	19	1.08	0.00
19	0	0.00	0.00	100.00	93.86	1.47	18	1.07	0.00
8	0	0.00	0.00	100.00	95.01	1.15	14	1.05	0.00
30	0	0.00	0.00	100.00	95.99	0.98	12	1.04	0.00
23	0	0.00	0.00	100.00	96.89	0.90	11	1.03	0.00
26	0	0.00	0.00	100.00	97.79	0.90	11	1.02	0.00
9	0	0.00	0.00	100.00	98.45	0.65	8	1.02	0.00
36	0	0.00	0.00	100.00	99.02	0.57	7	1.01	0.00
4	0	0.00	0.00	100.00	99.51	0.49	6	1.00	0.00
25	0	0.00	0.00	100.00	100.00	0.49	6	1.00	0.00

Node – a respective in the tree;
Cases Tgt. Class – the number of observations of target class (crisis) in any particular node;
% of Node Tgt. Class – the share of observations of target class in any particular node;
% Tgt. Class – the share of target observations in any particular node in the entire population of the given class;

Cum % Tgt. Class – the cumulative share of observations of the target class in the observations of the given class;
Cum % Pop – the cumulative share of observations in the entire population;
% Pop – the share of observations in any particular node in the entire population;
Cases in Node – the number of observations in any particular node;
Cum lift – the ratio of cumulative share of the target class to the cumulative share of observations;
Lift Pop – the ratio of the share of observations of the target class in any particular node to the share of total observations in the same node.

The Gains analysis shows which part of observations of the target class has been classified while using a certain segment of the entire dataset. In particular, the table and chart show that more than 30% of the crisis situations have been classified using only 15% observation of the entire dataset. In addition, about 20% of the crisis points have been separated in the 5th node of the tree, with a 47.4% probabilistic distribution.

7. The importance and relevance of leading indicators in the model is estimated by the use of algorithm in the CART which takes into account not only the role of that particular variable played in the final tree but also the fact of appearing as surrogates instead of any other variables with missing observations.

Unlike a regression analysis, the variables can be of high significance (importance), even if they never appear in the model (tree) as explanatory variables. This is due to the effect of the aforementioned "surrogate variables". The importance of factors in CART is estimated on the basis of the sum of improvement measures of goodness-of-split, in all segments of the tree regardless the variable acted as a main or surrogate splitter. Then a hierarchy of variable importance is constructed with score of 100 given to the variable with the highest sum of improvements, and relatively lower scores to others until it reaches 0.

In our model:

Table A8-A-5*: *Importance of factors

Variable	Score
OILPRICE	100.00
FISCDEF	95.24
ASSETPRICE	59.58
INFLATION	53.20
DOMCREDIT	39.00
M2_RES	34.32
OECD_GROWTH	30.55
SHTDEBT	30.24
DOLARIZATION	27.06
INTRATEDIFF	25.84
EXTDEBT	25.22
ECONGROWTH	19.18
CRED_DEPOSIT	18.85
CURRACC	17.36
RESERVES	15.61
EXPORT	15.08
FORASS_LIAB	14.85
CONTAGION	13.70
DEMOCRAT	11.98
REEROVER	9.55
REGIME2	9.06
TRANSFER	5.16
TOT	3.35
ELECTION	0.03

However, the results of importance of the variables are relative, depending on the tree structure, and therefore they should not be interpreted as absolute truth concerning variables. These estimates only point to any particular factor's ability to imitate the construction of the tree.

8. To have an understanding of the importance of the factors and especially of their threshold values, one should also refer to the role of variables in splitting the root or original node. As we know, the root split variable is the international oil price indicator that contributed to the biggest improvement in impurity measure.

Table A8-A-6: Root node splitters

	Competitor	Split	Improvement	N Left	N Right	N Missing
Main	OILPRICE	23.60500	0.07992	523	699	0
1	ASSETPRICE	-14.78764	0.05377	52	566	604
2	INFLATION	15.44300	0.04653	826	392	4
3	EXPORT	6.04093	0.03780	335	840	47
4	CRED_DEPOSIT	216.47983	0.03422	1049	153	20
5	INTRATEDIFF	1.27195	0.03170	132	906	184
6	ECONGROWTH	0.55213	0.02791	136	932	154
7	REEROVER	10.34594	0.02526	1042	47	133
8	EXTDEBT	32.13385	0.01987	283	755	184
9	OECD_GROWTH	1.75004	0.01980	147	811	264
10	M2_RES	351.88068	0.01917	914	87	221
11	CONTAGION	0	0.01560	425	797	0
12	DOMCREDIT	63.29155	0.01531	974	194	54
13	DOLARIZATION	43.80932	0.01495	586	446	190
14	RESERVES	10.70100	0.01447	316	764	142
15	SHTDEBT	4.06681	0.01162	52	1105	65
16	FORASS_LIAB	1636.12427	0.01143	1195	15	12
17	DEMOCRAT	-6,1,7,9	0.01094	345	821	56
18	TRANSFER	-33.67991	0.01061	272	822	128
19	FISCDEF	-46.26472	0.00773	10	699	513
20	CURRACC	7.65018	0.00659	1008	70	144
21	TOT	6.43895	0.00429	667	55	500
22	REGIME2	1	0.00333	367	855	0
23	ELECTION	0,1,2.1	0.00179	1145	77	0

9. The general predictive properties of the model are estimated both in-sample and out-of-sample. In the main tree, as much as 83,8% of total observations were classified correctly in-sample, 78,8%, out-of-sample; furthermore, of crisis points, as much as 96,4% and 82,5% were classified correctly in-sample and out-of-sample respectively.

Table A8-A-6: The results of in-sample forecast

Prediction Success–Learn–Count

Actual Class	Total Cases	Percent Correct	0 N=744	1 N=478
0	920	79.67	733	187
1	302	96.36	11	291
Total:	1,222.00			
Average:		88.02		
Overall % Correct:		83.80		

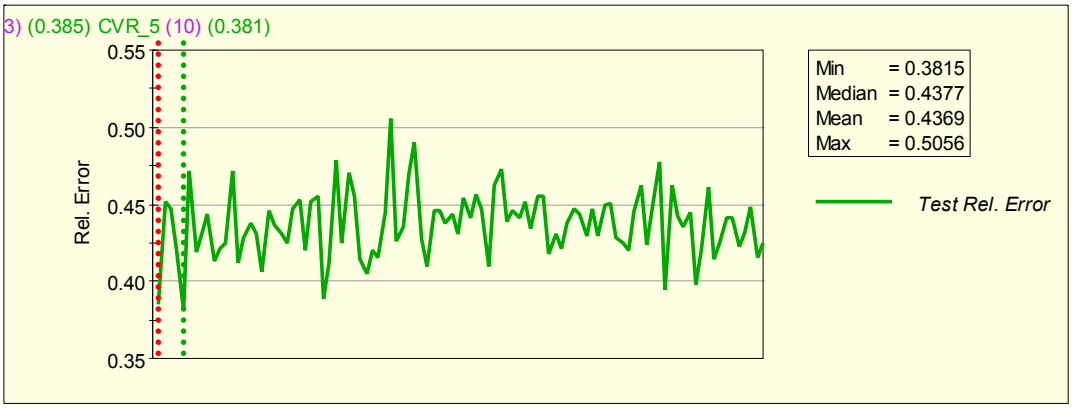
Table A8-A-7: The results of out-of-sample forecast

Prediction Success–Test–Count

Actual Class	Total Cases	Percent Correct	0 N=767	1 N=455
0	920	77.61	714	206
1	302	82.45	53	249
Total:	1,222.00			
Average:		80.03		
Overall % Correct:		78.81		

The CART modeling is characterized by defining a number of preliminary parameters until the very models are built. This means the key issue is to determine these parameters and decide on the best options. There are mechanisms in CART software package, which are designed to measure the model sensitivity to different parameters and decide on the best possible option. The package includes CART Batteries which gets the process automated. The results of some of the parameters concerning the size of nodes, the depth of the model, cross-validation and split rules and so on were addressed when we defined the main model parameters and restriction. Let us now review a couple of sensitivity tests which we consider appropriate from the standpoint of the results of the model.

The CVR test is used to check the sensitivity of cross-validation results produced from different observations. A one hundred time repetition of the test showed that a minimum level of cross-validation errors was 0.3815, the maximum level, 0.5056, and the average level, 0.4369. Because the estimate in our model is 0.399, it is not difficult to see that it is way below the average, so our main model has best properties among the trees of its class.



The LOVO (Leave One Variable Out) test is designed to build a number of trees, each with exclusion of one of explanatory variables. The goal here is to figure out if there are redundant or troubling factors. The results of *Table A8-A-8* suggest that the model results can improve a bit if variables such as terms of trade, remittances, and etc. are removed. However, because the size of their contribution is not large, exclusion of any such variables from the model does not make sense.

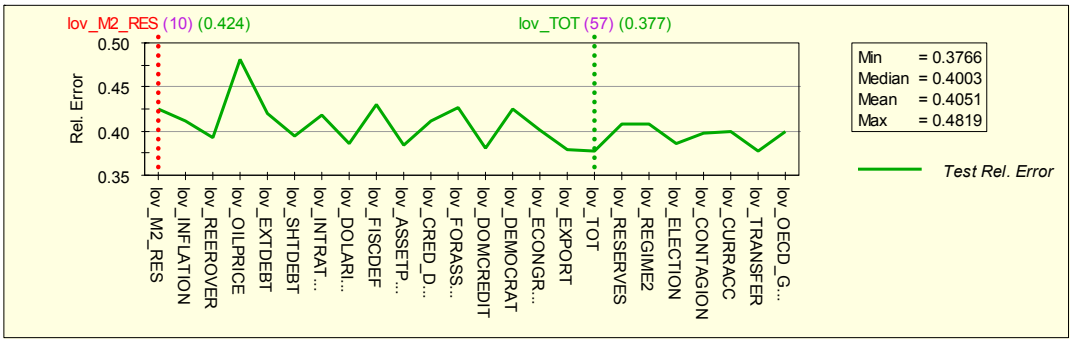


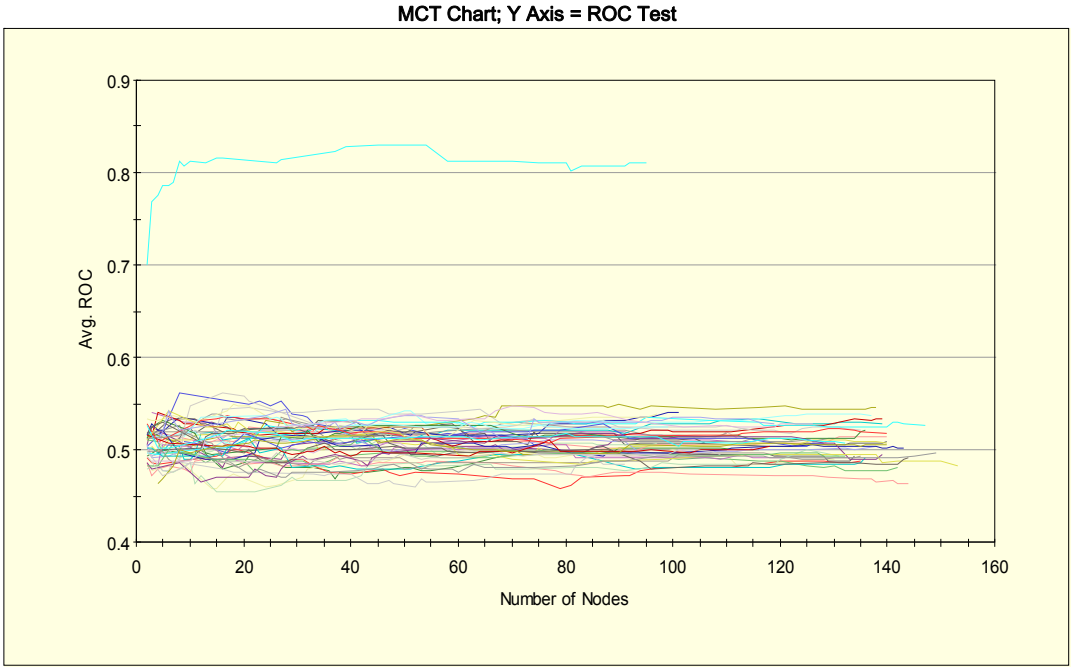
Table A8-A-8: LOVO Battery sensitivity tests results

Model Name	Opt. Terminal Nodes	Rel. Error	LOVO Predictor
Tree 19	57	0.3766	TOT
Tree 17	73	0.3779	TRANSFER
Tree 10	57	0.3789	EXPORT
Tree 11	55	0.3809	DOMCREDIT
Tree 15	47	0.3847	ASSETPRICE
Tree 24	44	0.3863	DOLARIZATION
Tree 2	58	0.3864	ELECTION
Tree 8	17	0.3925	REEROVER
Tree 6	36	0.3950	SHTDEBT
Tree 3	71	0.3976	CONTAGION
Tree 23	74	0.3990	OECD_GROWTH
Tree 9	73	0.4000	CURRACC
Tree 14	56	0.4006	ECONGROWTH
Tree 4	58	0.4084	REGIME2
Tree 5	58	0.4087	RESERVES
Tree 20	50	0.4108	CRED_DEPOSIT
Tree 13	15	0.4111	INFLATION
Tree 22	41	0.4184	INTRATEDIFF
Tree 7	29	0.4191	EXTDEBT
Tree 12	10	0.4245	M2_RES
Tree 1	55	0.4252	DEMOCRAT
Tree 18	54	0.4262	FORASS_LIAB
Tree 16	46	0.4308	FISCDEF
Tree 21	28	0.4819	OILPRICE

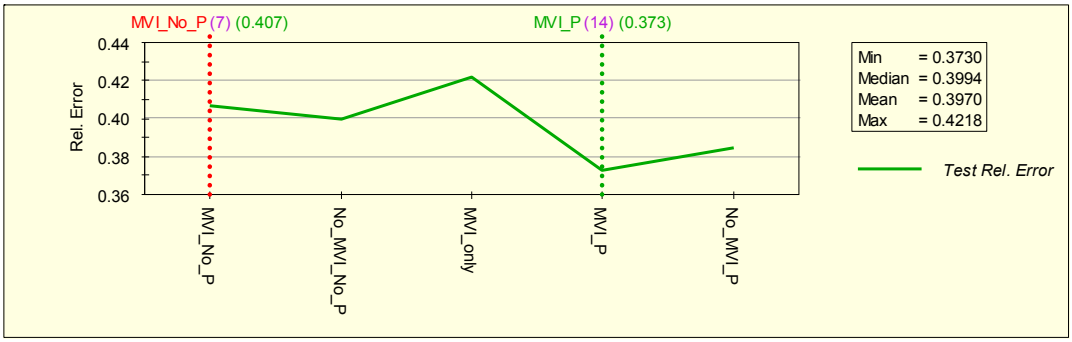
The MCT stands for a Monte Carlo Test designed to assess the significance of model properties. The dependent variable's points in the series get randomly mixed (this implies that all possible relationships between explanatory and dependent variables are demolished), and then a usual model is built. Once this process is repeated many times, the results obtained are to be compared with the main model results. In fact, this sensitivity test allows

determining the importance of correlations available in the model and of the information contained in explanatory variables.

The 20-time repeated tests showed that the 'demolished' models provide the value of 0.5216 of ROC indicator (ROC Test=0.5216), whereas in the main model the ROC Test=0.8227. This presumes that all models which would provide a ROC indicator above the values of 0.48-0.57 could be qualified as eligible. In our model it fairly outstrips its marginal value, so this can witness about the best properties of the model.



The MVI test allows identifying the role the missing points in variables play in the results of the model. The results of the test indicate that the inclusion of dummy variables to substitute missing points and the appropriate penalty scores assigned may reduce the model error up to 0.3730, which is just slightly lower than the 0.3994 value of the main model. Therefore, we can conclude that the problem of the missing values in our model was resolved in a possibly best manner by the use of surrogate variables.



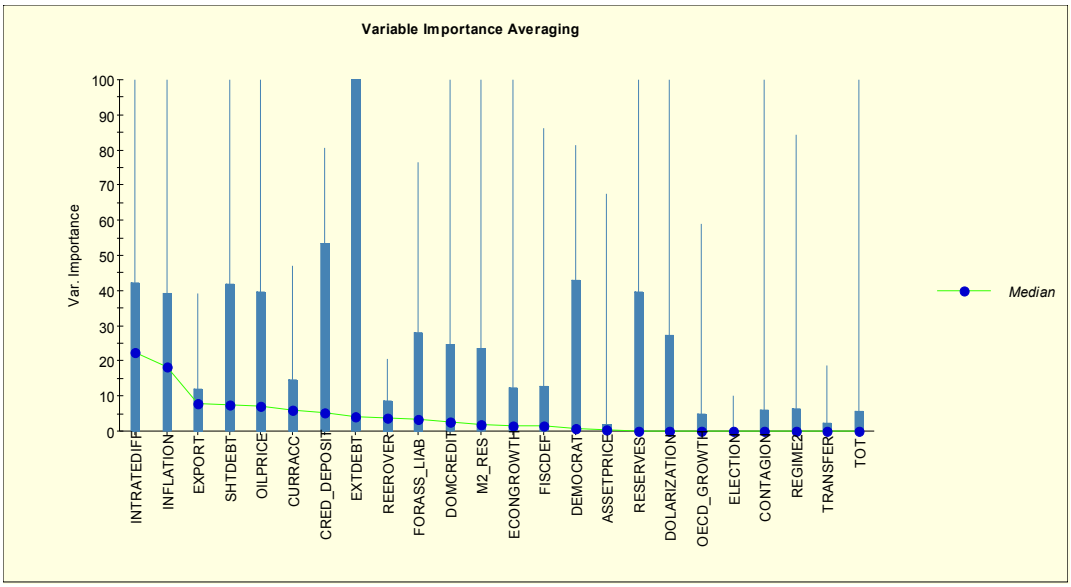
TARGET: The absence of multicolinearity in explanatory variables is an important prerequisite for any analysis. The use of a traditional covariance matrix can help us understand the correlations between individual peers but it cannot report relevant results if there are multiple as well as non-linear links. TARGET Battery makes it possible to resolve this problem. Here is the process: each of the explanatory variables, once chosen to be dependent variable, goes to the modeling process (classification trees are built for categorical and regression trees are built for continuous variables) while the other factors are considered as explanatory factors. The resulting model properties point to the correlations between any given variable and other variables, while the importance of the variables shows which factors appeared in models.

As shown in *Table A8-A-9*, the mostly explained are indicators such as OILPRICE, RESERVES, OECD Growth, CRED_DEPOSIT, EXTDEBT, SHTDEBT. Whereas, indicators such as overvaluation of the exchange rate, export or inflation, were not possible to forecast by any reasonable combination of the factors (Rel.Error>1).

Table A8-A-9: TARGET Battery test results

Model Name	1SE Terminal Nodes	Rel. Error	Target
Tree 21	6	0.2005	OILPRICE
Tree 5	70	0.3017	RESERVES
Tree 23	16	0.3106	OECD_GROWTH
Tree 20	47	0.3419	CRED_DEPOSIT
Tree 7	38	0.3451	EXTDEBT
Tree 6	41	0.3588	SHTDEBT
Tree 18	21	0.3702	FORASS_LIAB
Tree 24	14	0.4973	DOLARIZATION
Tree 12	17	0.5181	M2_RES
Tree 16	2	0.6281	FISCDEF
Tree 11	4	0.6793	DOMCREDIT
Tree 22	2	0.7986	INTRATEDIFF
Tree 9	16	0.8715	CURRACC
Tree 15	2	1.0121	ASSETPRICE
Tree 8	2	1.0333	REEROVER
Tree 17	3	1.0434	TRANSFER
Tree 10	4	1.1329	EXPORT
Tree 13	2	1.1958	INFLATION
Tree 14	3	1.3423	ECONGROWTH
Tree 19	2	1.4254	TOT

It is noteworthy that INTRATEDIFF has the biggest role in the explanation of the rest of variables, and has an average 23% importance rate in all variables.



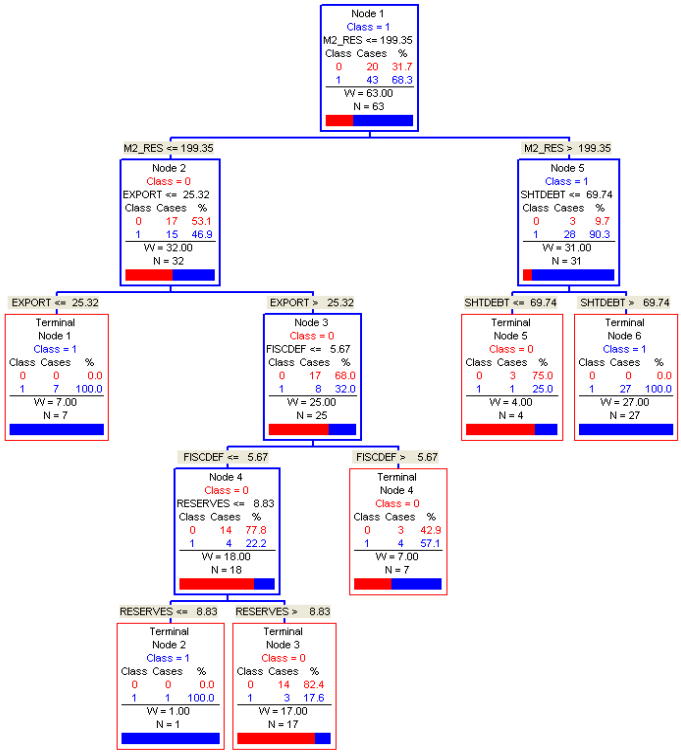
Appendix 8-A: The results of modeling of an auxiliary segment separated from the main model*[83]

Data Sample
63 Records Total

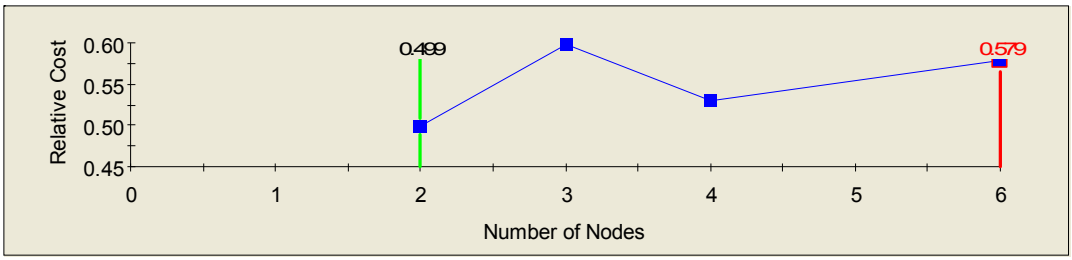
Class	Learn	%	Total
0	43	68.25	43
1	20	31.75	20
Total:	63	100.00	63

[83] *Other characteristics of the model can be obtained from the author.*

Classification tree topology for: CRISIS



Error Curve



Variable Importance

Variable	Score	
M2_RES	100.00	||||||||||||||||||||||||||||||||||||
DOMCREDIT	84.98	||||||||||||||||||||||||||||||
RESERVES	60.06	||||||||||||||||||||
INTRATEDIFF	50.32	||||||||||||||||
SHTDEBT	41.16	||||||||||||||
EXPORT	35.44	||||||||||||
DOLARIZATION	32.54	||||||||||
EXTDEBT	29.11	||||||||||
FISCDEF	28.16	||||||||||
FORASS_LIAB	20.37	|||||||
INFLATION	10.04	|||
TRANSFER	6.44	||
REGIME2	5.10		
REEROVER	2.52	

Prediction Success--Learn--Count

Actual Class	Total Cases	Percent Correct	0 N=28	1 N=35
0	20	100.00	20	0
1	43	81.40	8	35
Total:	63.00			
Average:		90.70		
Overall % Correct:		87.30		

Prediction Success--Test--Count

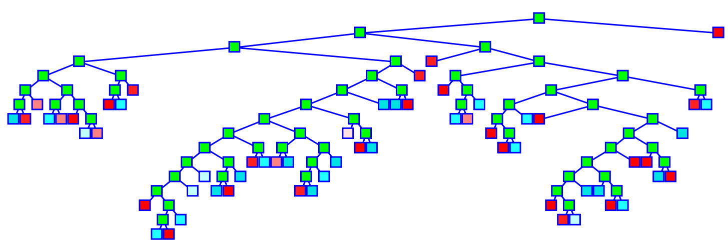
Actual Class	Total Cases	Percent Correct	0 N=26	1 N=37
0	20	70.00	14	6
1	43	72.09	12	31
Total:	63.00			
Average:		71.05		
Overall % Correct:		71.43		

Appendix 8-B: The results of Panel alternative model 1[84]

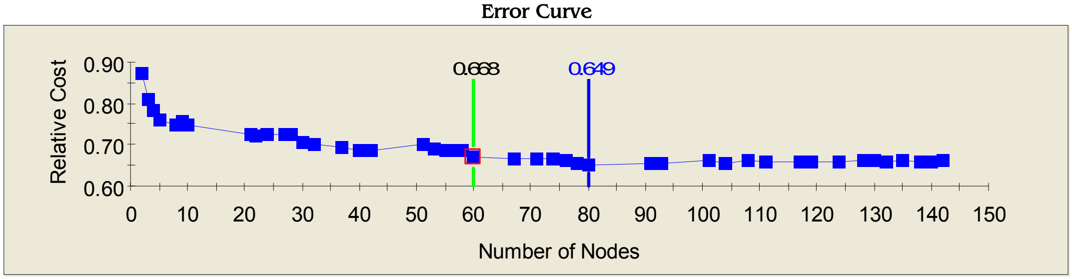
Data Sample
1218 Records Total

Class	Learn	%	Total
0	580	47.62	580
1	638	52.38	638
Total:	1218	100.00	1218

Classification tree topology for: CRISIS



Error Curve



Variable Importance

Variable	Score	
OILPRICE	100.00	||||||||||||||||||||||||||||||||||||||||
ASSETPRICE	87.25	|||||||||||||||||||||||||||||||||||
M2_RES	68.97	||||||||||||||||||||||||||||
FORASS_LIAB	62.79	|||||||||||||||||||||||||
OECD_GROWTH	62.71	|||||||||||||||||||||||||
TOT	49.40	||||||||||||||||||||
REEROVER	46.63	|||||||||||||||||||
FISCDEF	41.39	|||||||||||||||||
EXTDEBT	39.25	||||||||||||||||
CRED_DEPOSIT	33.88	||||||||||||||

[84] *The detailed description of the tree as well as other characteristics of the model can be obtained from the author.*

INFLATION	32.78	|||||||||||
RESERVES	30.86	|||||||||||
SHTDEBT	29.57	|||||||||||
DEMOCRAT	25.51	|||||||||
DOLARIZATION	24.82	|||||||||
INTRATEDIFF	24.64	|||||||||
DOMCREDIT	21.38	|||||||
ECONGROWTH	21.02	|||||||
TRANSFER	17.02	||||||
CURRACC	14.48	|||||
EXPORT	8.54	|||
CONTAGION	4.47		
REGIME2	3.39	
ELECTION	1.95	

Prediction Success–Learn–Count

Actual Class	Total Cases	Percent Correct	0 N=614	1 N=604
0	580	86.38	501	79
1	638	82.29	113	525
Total:	1,218.00			
Average:		84.33		
Overall % Correct:		84.24		

Prediction Success–Test–Count

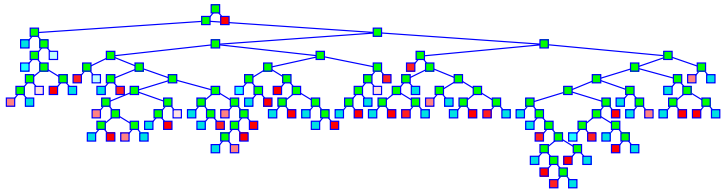
Actual Class	Total Cases	Percent Correct	0 N=622	1 N=596
0	580	68.45	397	183
1	638	64.73	225	413
Total:	1,218.00			
Average:		66.59		
Overall % Correct:		66.50		

Appendix 8-C: The results of Panel alternative model 2[85]

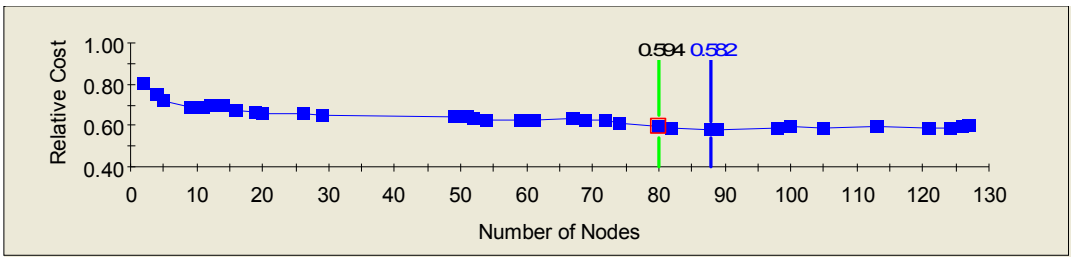
Data Sample
1222 Records Total

Class	Learn	%	Total
0	765	62.60	765
1	457	37.40	457
Total:	1222	100.00	1222

Classification tree topology for: CRISIS



Error Curve



[85] *The detailed description of the tree as well as other characteristics of the model can be obtained from the author.*

Variable Importance

Variable	Score	
ASSETPRICE	100.00	
FISCDEF	65.96	
OILPRICE	55.78	
DOLARIZATION	50.51	
M2_RES	41.46	
ECONGROWTH	38.39	
OECD_GROWTH	38.19	
FORASS_LIAB	37.25	
INTRATEDIFF	36.58	
SHTDEBT	35.60	
REEROVER	33.43	
TOT	32.99	
CRED_DEPOSIT	31.73	
EXTDEBT	30.22	
DEMOCRAT	28.33	
TRANSFER	27.22	
DOMCREDIT	25.00	
CURRACC	23.56	
RESERVES	23.49	
INFLATION	22.53	
EXPORT	20.63	
REGIME2	9.06	
CONTAGION	4.31	
ELECTION	3.80	

Prediction Success–Learn–Count

Actual Class	Total Cases	Percent Correct	0 N=694	1 N=528
0	765	86.67	663	102
1	457	93.22	31	426
Total:	1,222.00			
Average:		89.94		
Overall % Correct:		89.12		

Prediction Success–Test–Count

Actual Class	Total Cases	Percent Correct	0 N=698	1 N=524
0	765	72.29	553	212
1	457	68.27	145	312
Total:	1,222.00			
Average:		70.28		
Overall % Correct:		70.79		

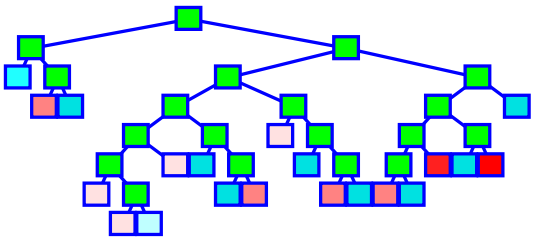
Appendix 8-D: The results of Panel alternative model 3[86]

Data Sample

1180 Records Total

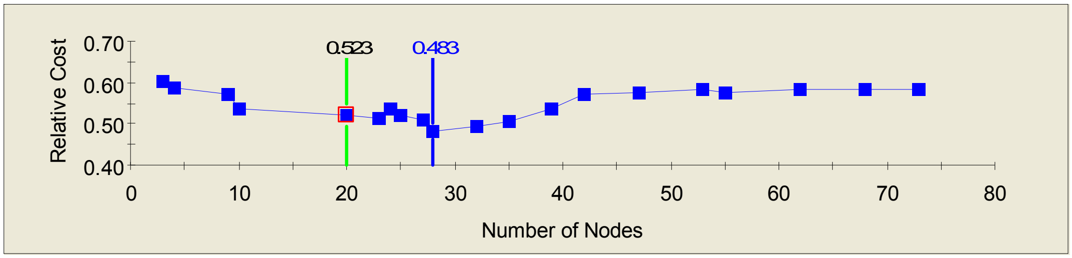
Class	Learn	%	Total
0	1056	89.49	1056
1	124	10.51	124
Total:	1180	100.00	1180

Classification tree topology for: CRISIS



[86] *The detailed description of the tree as well as other characteristics of the model can be obtained from the author.*

Error Curve



Variable Importance

<table>
<tr><th>Variable</th><th>Score</th><th></th></tr>
<tr><td>ASSETPRICE2</td><td>100.00</td><td>||||||||||||||||||||||||||||||||||||||||</td></tr>
<tr><td>OILPRICE1</td><td>32.19</td><td>|||||||||||||</td></tr>
<tr><td>DOLAR2</td><td>24.58</td><td>||||||||||</td></tr>
<tr><td>FISCDEF1</td><td>22.59</td><td>|||||||||</td></tr>
<tr><td>INFLATION1</td><td>20.44</td><td>||||||||</td></tr>
<tr><td>CONTAGION</td><td>18.02</td><td>|||||||</td></tr>
<tr><td>ECONGROWTH1</td><td>17.82</td><td>|||||||</td></tr>
<tr><td>CRED_DEPOSIT1</td><td>16.81</td><td>||||||</td></tr>
<tr><td>EXTDEBT1</td><td>13.48</td><td>|||||</td></tr>
<tr><td>REROV1</td><td>13.30</td><td>|||||</td></tr>
<tr><td>DEMOCRAT</td><td>10.97</td><td>||||</td></tr>
<tr><td>OECD_GROWTH4</td><td>10.10</td><td>|||</td></tr>
<tr><td>M2_RES2</td><td>9.49</td><td>|||</td></tr>
<tr><td>SHTDEBT3</td><td>9.17</td><td>|||</td></tr>
<tr><td>INTRATEDIFF1</td><td>8.86</td><td>|||</td></tr>
<tr><td>DOMCREDIT3</td><td>6.11</td><td>||</td></tr>
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<tr><td>TRANSFER4</td><td>2.56</td><td></td></tr>
<tr><td>REGIME3LEV</td><td>0.51</td><td></td></tr>
</table>

Prediction Success--Learn--Count

Actual Class	Total Cases	Percent Correct	0 N=854	1 N=326
0	1,056	79.73	842	214
1	124	90.32	12	112
Total:	1,180.00			
Average:		85.03		
Overall % Correct:		80.85		

Prediction Success--Test--Count

Actual Class	Total Cases	Percent Correct	0 N=780	1 N=400
0	1,056	71.12	751	305
1	124	76.61	29	95
Total:	1,180.00			
Average:		73.87		
Overall % Correct:		71.69		

Appendix 8-E: The results of Panel alternative model 4[87]

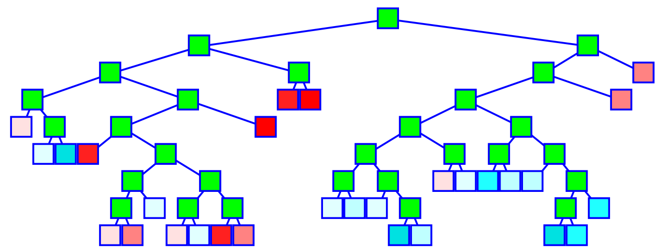
Data Sample

1180 Records Total

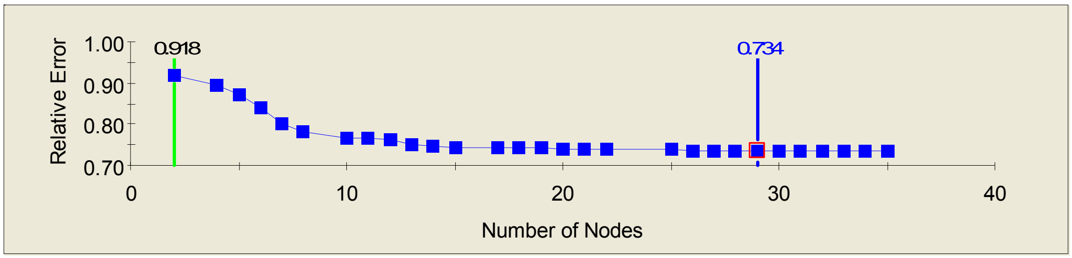
Class	Learn	%	Total
Total:	1180	100.00	1180

[87] *The detailed description of the tree as well as other characteristics of the model can be obtained from the author.*

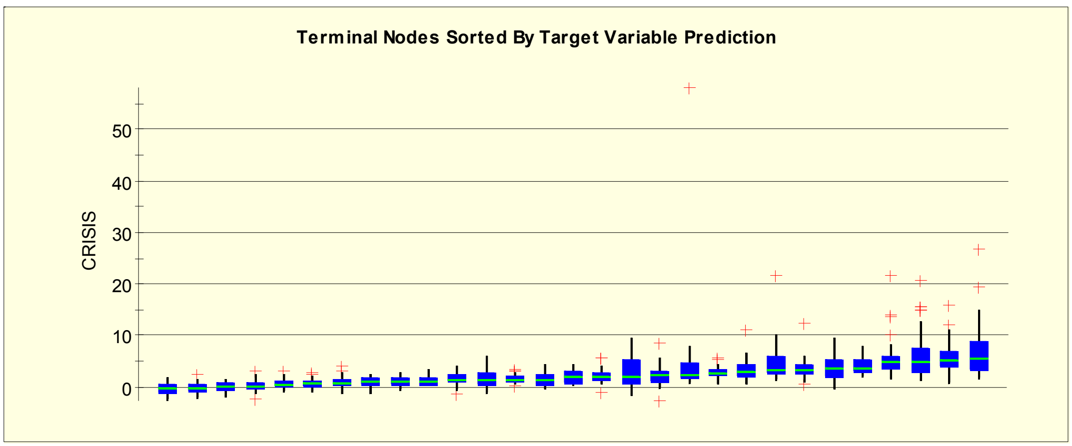
Regression tree topology for: CRISIS



Error Curve



Terminal Nodes



Variable Importance

Variable	Score	
OILPRICE1	100.00	||||||||||||||||||||||||||||||||||||||||
INFLATION1	98.73	|||||||||||||||||||||||||||||||||||||||
M2_RES2	85.69	||||||||||||||||||||||||||||||||||
CONTAGION	67.61	|||||||||||||||||||||||||||
EXTDEBT1	46.31	|||||||||||||||||||
INTRATEDIFF1	40.83	|||||||||||||||||
REROV1	39.90	||||||||||||||||
DOMCREDIT3	38.23	|||||||||||||||
RES4	31.49	|||||||||||||
REGIME3LEV	24.28	||||||||||
DEMOCRAT	21.79	|||||||||
CRED_DEPOSIT1	12.13	||||
SHTDEBT3	8.47	|||
DOLAR2	6.28	||
CA4	4.63	|
OECD_GROWTH4	4.20	|
ASSETPRICE2	4.03	|
FORASS_LIAB4	3.32	
EXPORT3	2.64	
ECONGROWTH1	2.13	
TRANSFER4	1.62	
FISCDEF1	0.76	
TOT1	0.29	
ELECTION4	0.00	

Appendix 8-F: Comparison of splitters of the root node in the two models

Splitters of the root node in binary index lag model
Main Splitter Improvement = 0.09492

	Competitor	Split	Improvement	N Left	N Right	N Missing
Main	ASSETPRICE2	-4.56167	0.09492	135	481	564
1	CONTAGION	0	0.08461	416	764	0
2	OILPRICE1	23.60500	0.08447	463	717	0
3	ECONGROWTH1	1.41162	0.06404	164	901	115
4	INFLATION1	17.36325	0.05794	865	314	1
5	CRED_DEPOSIT1	223.23669	0.04354	1044	127	9
6	REROV1	4.78957	0.03979	936	137	107
7	INTRATEDIFF1	-0.16335	0.03958	87	939	154
8	OECD_GROWTH4	2.24037	0.03833	210	706	264
9	M2_RES2	364.61993	0.03623	920	64	196
10	EXTDEBT1	31.22720	0.02898	257	770	153
11	EXPORT3	6.03176	0.02886	330	814	36
12	FISCDEF1	-6.60509	0.02136	63	644	473
13	TRANSFER4	-107.65033	0.02034	130	931	119
14	SHTDEBT3	4.06681	0.01922	50	1074	56
15	DEMOCRAT	1,9	0.01820	150	938	92
16	DOLAR2	73.30055	0.01648	920	58	202
17	RES4	10.10812	0.01494	281	765	134
18	DOMCREDIT3	51.43970	0.01408	885	252	43
19	FORASS_LIAB4	1001.94928	0.01097	1138	30	12
20	TOT1	-0.34092	0.00676	264	434	482
21	CA4	-13.66245	0.00522	130	916	134
22	REGIME3LEV	1	0.00338	347	791	42
23	ELECTION4	0,1,2,	0.00288	1131	49	0
		2.1				

Splitters of the root node in continuous EMP index model
Main Splitter Improvement = 1.30952

	Competitor	Split	Improvement	N Left	N Right	N Missing
Main	OILPRICE1	24.56000	1.30952	484	696	0
1	INFLATION1	24.67720	1.27019	939	240	1
2	REROV1	10.34594	1.26751	1031	42	107
3	CONTAGION	0	1.09567	416	764	0
4	M2_RES2	465.70514	0.93234	959	25	196
5	ASSETPRICE2	-19.58232	0.70093	32	584	564
6	ECONGROWTH1	-0.33521	0.65718	111	954	115
7	INTRATEDIFF1	-1.86500	0.60355	58	968	154
8	DOMCREDIT3	61.49816	0.55351	947	190	43
9	CRED_DEPOSIT1	220.34204	0.52208	1039	132	9
10	RES4	10.36186	0.47501	290	756	134
11	FISCDEF1	-6.60509	0.41477	63	644	473
12	EXPORT3	6.03176	0.41336	330	814	36
13	REGIME3LEV	1	0.32417	347	791	42
14	DEMOCRAT	-7,-6,-5,	0.29323	1040	48	92
		1,5,6,7,				
		8,9,10				
15	OECD_GROWTH4	3.59235	0.22358	772	144	264
16	EXTDEBT1	120.86922	0.18309	1002	25	153
17	SHTDEBT3	4.06681	0.10421	50	1074	56
18	CA4	-3.95147	0.10391	585	461	134
19	DOLAR2	23.13165	0.09316	220	758	202
20	TOT1	-2.94011	0.09051	128	570	482
21	FORASS_LIAB4	415.26443	0.05866	1067	101	12
22	TRANSFER4	-7.76749	0.05700	414	647	119
23	ELECTION4	0,1,2,	0.01779	1131	49	0
		2.1				

Appendix 8-G: The results of the model built on Armenian data[88]

Tree Sequence

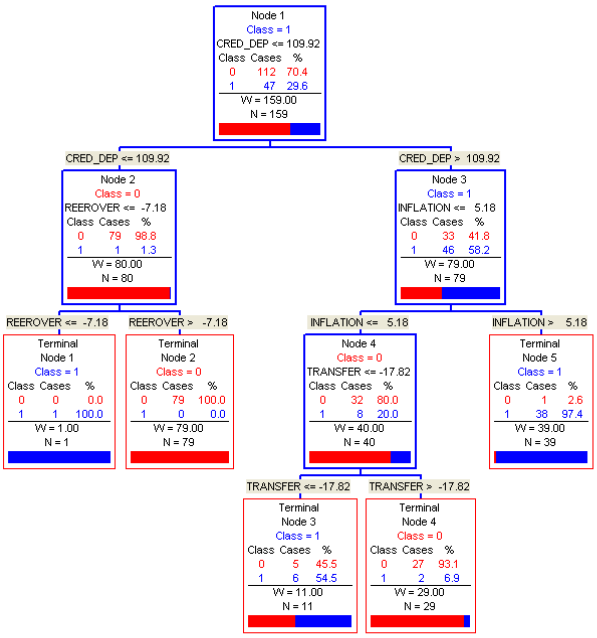
Tree Number	Terminal Nodes	Cross-Validated Relative Cost	Resubstitution Relative Cost	Complexity
1	6	0.17230 ± 0.05244	0.08720	0.00000
2**	5	0.15103 + 0.04903	0.09612	0.00449
3	4	0.21486 ± 0.05819	0.11740	0.01065
4	3	0.33777 ± 0.06738	0.20042	0.04152
5	2	0.35847 ± 0.05592	0.31592	0.05776
6	1	1.00000 ± 0.00000	1.00000	0.34205

* *Minimum Cost*
** *Optimal*

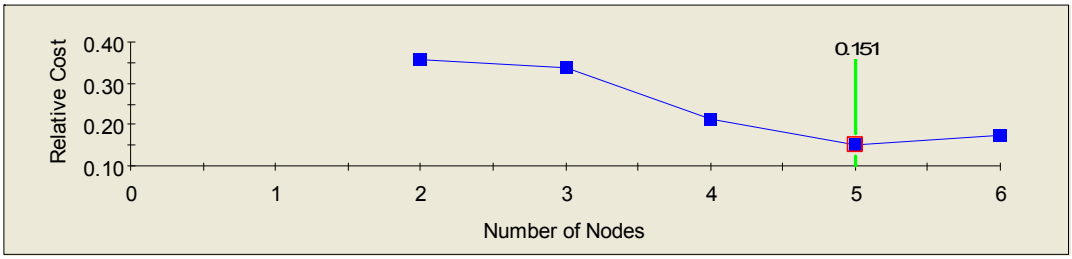
Data Sample
159 Records Total

Class	Learn	%	Total
1	47	29.56	47
0	112	70.44	112
Total:	159	100.00	159

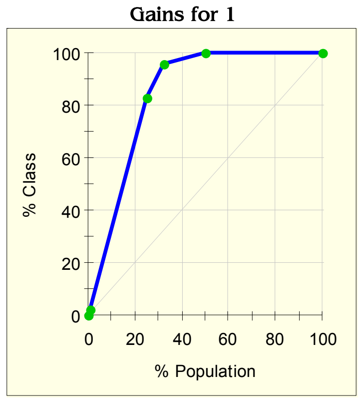
Classification tree topology for: CRISIS



Error Curve



[88] *Other characteristics of the model can be obtained from the author.*



Navigator 1 (5): Tree Summary Reports: Gains Data for 1

Node	Cases Tgt. Class	% of Node Tgt. Class	% Tgt. Class	Cum % Tgt. Class	Cum % Pop	% Pop	Cases in Node	Cum lift	Lift Pop
1	1	100.00	2.13	2.13	0.63	0.63	1	3.38	3.38
5	38	97.44	80.85	82.98	25.16	24.53	39	3.30	3.30
3	6	54.55	12.77	95.74	32.08	6.92	11	2.98	1.85
4	2	6.90	4.26	100.00	50.31	18.24	29	1.99	0.23
2	0	0.00	0.00	100.00	100.00	49.69	79	1.00	0.00

Variable Importance

Variable	Score	
CRED_DEP	100.00	||||||||||||||||||||||||||||||||||||||||||
FORASSET_LAIB	99.05	||||||||||||||||||||||||||||||||||||||||||
SHTDEBT	70.67	|||||||||||||||||||||||||||||
REGIME	69.80	|||||||||||||||||||||||||||||
ECOGROWTH	64.36	|||||||||||||||||||||||||||
CONTAGION	41.50	|||||||||||||||||
INFLATION	40.74	|||||||||||||||||
TRANSFER	35.54	||||||||||||||
M2_RES	30.88	||||||||||||
DEMOCRACY	19.22	|||||||
EXTDEBT	16.31	||||||
EXPORT	15.32	||||||
RESERVES	12.10	||||
REEROVER	7.58	||
CREDIT	7.58	||
GLOBALECOGROWTH	7.58	||
OILPRICE	2.54	
CURRACC	0.00	

Prediction Success–Learn–Count

Actual Class	Total Cases	Percent Correct	0 N=108	1 N=51
0	112	94.64	106	6
1	47	95.74	2	45
Total:	159.00			
Average:		95.19		
Overall % Correct:		94.97		

Prediction Success–Test–Count

Actual Class	Total Cases	Percent Correct	0 N=112	1 N=47
0	112	95.54	107	5
1	47	89.36	5	42
Total:	159.00			
Average:		92.45		
Overall % Correct:		93.71		

Appendix 9: Methodology for building the regression tree

As was mentioned earlier, CART builds regression trees when a dependent or explained variable is continuous. The process of building regression trees is similar to the building of classification trees but priors as well as class assignment rules are not used here. What are used instead are final statistics (characteristics) of terminal nodes; in addition other splitting, goodness-of-split rules and predictive accuracy measures are used.

Building a regression trees is also based on three elements:

- group of questions underlying the split,
- splitting rules and goodness-of-split criteria,
- final statistics of terminal nodes.

The last element is inherent to regression trees, since there are no classes here, so the final nodes will be differentiated by statistical characteristics of dependent variable.

The main purpose of CART regression is to obtain, in the form of a tree, a forecast or prediction rule which aims at two targets: 1/ accurately predict the value of a dependent variable based on explanatory variables, and 2/ explain the links between independent and dependent variables.

The regression forecast in the form of a tree is constructed, gradually identifying and further reducing heterogeneity in the data, which is reflected as variance. In each terminal node the mean of the dependent variable is treated as predicted. If the goal of a regression tree is explanation it will be realized by tracking a path from the upper part of the tree to the appropriate node.

Sample-Splitting rules and goodness-of-split criterion: There are two rules for splitting nodes in the regression trees or two types of impurity functions, such as: 1/ the least square function (LS), and 2/ the least absolute deviation function (LAD). Since the mechanism for the two is the same, let us review the first only.

For LS criterion the impurity measure of a node is described by the sum of squares of intranode cases:

$$SS(t) = \sum_{i=1}^{N_t} (y_{it} - \bar{y}_t)^2$$

where: y_{it} *- is the values of dependent variable in the node t,* $\bar{y}_t$ *- is the mean of the dependent variable in the node t.*

For the given impurity function $SS(t)$ and split *s*, which separates the observations into right (t_r) and left (t_l) sub-samples, the goodness-of-split criterion is calculated as follows:

$$\phi(s,t) = SS(t) - SS(t_r) - SS(t_l)$$

Of the divisions made on a basis of all variables and their respective values, one shall choose the one for which the specified criterion is the maximum.

As an alternative to LS, we may use the method of weighted variance in the right and left nodes where the weights are the share of observations in a particular node in the total observation of parent node : $p(t)=N_t/N$. Let $s^2(t)$ is the variance of a dependent variable in *t* node:

$$s^2(t) = \frac{1}{N_t} \sum_{i=1}^{N_t} [y_{it} - \bar{y}_t]^2$$

In this case, the goodness-of-split is estimated as follows:

$$\phi(s,t) = s^2(t) - [p_l s^2(t) + p_r s^2(t)]$$

The best split is the one for which the specified expression is the biggest or for which the sum of weighted variances $[p_l s^2(t) + p_r s^2(t)]$ is the smallest.

In splitting, because observations of the parent node are distributed into child-nodes, the average of the variable in one of them shall always be smaller than that in the parent node.

The construction of the tree according to the main principles of regression tree building is carried out in the following steps:

1. CART, with the use of its splitting rule and goodness-of-split criterion, divides the combination into two groups and selects the split (a variable and its threshold value) which utmost reduces the impurity measure.
2. Since this method uses a recursive algorithm, the above mentioned steps apply to every non-terminal node, and the biggest possible tree is built.
3. Finally, CART uses its pruning algorithm, gets series of sequentially nested and pruned subtrees and chooses the best tree.

It should be noted that, for cross-validation evaluation of the qualitative properties of the trees, the mean squared error is applied in case of LS and the mean absolute deviation for LAD. . As a result, the best tree is chosen by applying the one standard deviation rule to the indicators specified.

After the best tree is constructed, the descriptors of the variable shall be calculated and presented for terminal nodes: if LS is chosen as a splitting rule, the mean is delivered as the forecast, whereas LAD is chosen, the median is delivered as the forecast.

Appendix 10: Types of currency crises

Nº	Description	Current Account	Monetary Expansion, Excess Finance	Budget Deficit	Debt Crisis	Capital Account Crisis	Self-fulfilling		Crises	
							Adverse environment	Self-fulfilling	Number of crises in the node	Probability
1	OILPRICE <= 23.605 && **OECD_GROWTH <= 1.56697 &&** EXTDEBT <= 24.2974						*		5	41.67
2	OILPRICE <= 23.605 && OECD_GROWTH <= 1.56697 && **EXTDEBT > 24.2974**				*				1	2.38
3	OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && **ASSETPRICE <= -12.7006 &&** **RESERVES <= 19.3121**		*						45	62.5
5	OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && ASSETPRICE > -12.7006 && **FISCDEF <= -6.57797**			*					63	47.37
6	OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && ASSETPRICE > -12.7006 && ASSETPRICE <= 23.7437 && **FISCDEF > -6.57797 &&** **FISCDEF <= -3.2044 &&** DOLARIZATION <= 27.3282 && M2_RES <= 147.011			*					6	60
7	OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && ASSETPRICE > -12.7006 && ASSETPRICE <= 23.7437 && **FISCDEF > -6.57797 &&** **FISCDEF <= -3.2044 &&** DOLARIZATION <= 27.3282 && **M2_RES > 147.011 &&** INFLATION <= 2.1101		*						2	100
10	REGIME2 == 2 || REGIME2 == 3 && OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && ASSETPRICE > -12.7006 && ASSETPRICE <= 23.7437 && **FISCDEF > -6.57797 &&** **FISCDEF <= -3.2044 &&** **DOLARIZATION > 27.3282**						*		20	80
11	OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && ASSETPRICE > -12.7006 && ASSETPRICE <= 23.7437 && **FISCDEF > -3.2044 &&** **FISCDEF <= -3.05659**							*	4	80
13	OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && ASSETPRICE > -12.7006 && ASSETPRICE <= 23.7437 && FISCDEF > -3.05659 && FISCDEF <= -1.63419 && M2_RES <= 313.442 && **INFLATION > 26.0065**		*						7	58.33
14	OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && ASSETPRICE > -12.7006 && ASSETPRICE <= 23.7437 && FISCDEF > -3.05659 && FISCDEF <= -1.63419 && **M2_RES > 313.442**		*						1	33.33
15	OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && **FISCDEF > -6.57797 &&** **FISCDEF <= -1.63419 &&** ASSETPRICE > 23.7437			*					5	45.46
16	OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && ASSETPRICE > -12.7006 && FISCDEF > -1.63419 && INTRATEDIFF <= 1.7415							*	25	71.43
17	OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && FISCDEF > -1.63419 && **INTRATEDIFF > 1.7415 &&** ASSETPRICE > -12.7006 && ASSETPRICE <= -1.65255 && **EXPORT <= -8.51742**	*							3	75

Nº	Description	Current Account	Monetary Expansion, Excess Finance	Budget Deficit	Debt Crisis	Capital Account Crisis	Self-fulfilling		Crises	
							Adverse environment	Self-fulfilling	Number of crises in the node	Probability
18	OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && FISCDEF > -1.63419 && **INTRATEDIFF > 1.7415 &&** ASSETPRICE > -12.7006 && ASSETPRICE <= -1.65255 && EXPORT > -8.51742 && SHTDEBT <= 8.34482		*						4	100
20	OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && FISCDEF > -1.63419 && **INTRATEDIFF > 1.7415 &&** ASSETPRICE > -1.65255 && **CURRACC <= -1.60386 &&** EXTDEBT <= 14.1113	*							1	9.09
21	OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && FISCDEF > -1.63419 && **INTRATEDIFF > 1.7415 &&** ASSETPRICE > -1.65255 && **CURRACC <= -1.60386 && EXTDEBT > 14.1113 &&** DOLARIZATION <= 23.6321				*				1	8.33
22	OILPRICE <= 23.605 && OECD_GROWTH > 1.56697 && FISCDEF > -1.63419 && **INTRATEDIFF > 1.7415 &&** ASSETPRICE > -1.65255 && **CURRACC <= -1.60386 && EXTDEBT > 14.1113 && DOLARIZATION > 23.6321**						*		27	50
24	OILPRICE > 23.605 && OILPRICE <= 82.025 && DOMCREDIT <= -5.65811 && DOLARIZATION <= 42.8958 && M2_RES <= 82.454							*	6	75
27	OILPRICE > 23.605 && OILPRICE <= 82.025 && DOMCREDIT <= -5.65811 && **DOLARIZATION > 42.8958 &&** RESERVES > 24.0601						*		5	100
28	DOMCREDIT > -5.65811 && INFLATION <= 29.6307 && OILPRICE > 23.605 && OILPRICE <= 72.565 && **ECONGROWTH <= -4.35711**						*		2	66.67
29	DOMCREDIT > -5.65811 && INFLATION <= 29.6307 && OILPRICE > 23.605 && OILPRICE <= 72.565 && ECONGROWTH > -4.35711							*	7	1.3
31	DOMCREDIT > -5.65811 && INFLATION <= 29.6307 && OILPRICE > 72.565 && OILPRICE <= 82.025 && TRANSFER > 28.5658							*	5	55.56
33	**REGIME2 == 1** && OILPRICE > 23.605 && OILPRICE <= 82.025 && **INFLATION > 29.6307 &&** DOMCREDIT > -5.65811 && DOMCREDIT <= 60.2076		*						2	100
34	OILPRICE > 23.605 && OILPRICE <= 82.025 && **INFLATION > 29.6307 && DOMCREDIT > 60.2076 &&** DOLARIZATION <= 57.0519		*						11	84.63
35	OILPRICE > 23.605 && OILPRICE <= 82.025 && **INFLATION > 29.6307 && DOMCREDIT > 60.2076 && DOLARIZATION > 57.0519**						*		1	11.11
37*	**OILPRICE > 82.025 && CURRACC > -23.6052**								43	76.79

** The 37th node is not described as it has been reviewed separately (see Appendix 8-A*)*

***Table DA-1*: Data source matrix**

	Albania	Armenia	Azerbaijan	Belarus	Bulgaria	Croatia	Czech Rep	Estonia	Georgia	Hungary	Kazakhstan	Latvia	Lithuania	Macedonia	Moldova	Poland	Romania	Russia	Slovakia	Turkey	Ukraine
Nominal exchange rate (monthly average)	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
Nominal exchange rate (quarterly average)	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
Nominal exchange rate (end of period)	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
International reserves	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
CB net foreign assets		UNISIS																			
Banks' corresponding accounts in foreign currency		UNISIS																			
Money market rate	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
US Federal Funds rate	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
Lending rate	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	-	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	-	IFS
Inflation	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
Exports	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
Broad money, M2	IFS+ Bank of Albania	UNISIS	IFS	IFS	IFS	Croatian National Bank	IFS	IFS	IFS+ National Bank of Georgia	IFS	IFS+ National Bank of Kazakhstan	IFS	IFS+ Bank of Lithuania	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
Domestic credit	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
Deposits	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
Banks' foreign assets	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
Banks' foreign liabilities	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
Real exchange rate	-	UNISIS	CB of Azerbaijan	National Bank of Belarus	IFS	IFS	IFS	BIS	IFS	IFS	National Bank of Kazakhstan	BIS	BIS	IFS	IFS	IFS	IFS	IFS	IFS	BIS	IFS
Nominal GDP	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS+ Stat. Service of Moldova	IFS+ Eurostat	IFS+ EuroStat	IFS+ Stat. Service of Russia	IFS	IFS	IFS
Current account	IFS+ Bank of Albania	IFS	IFS	IFS+ National Bank of Belarus	IFS	IFS	IFS	IFS	IFS+ National Bank of Georgia	IFS	IFS+ National Bank of Kazakhstan	IFS	IFS+ Bank of Lithuania	IFS+ National Bank of Macedonia	IFS	IFS	IFS	IFS	IFS	IFS	IFS
Remittances	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
Short-term external debt	WDI	BIS+ WDI	WDI	BIS	Bulgarian National Bank + WDI	BIS+Croatian National Bank+WDI	BIS	BIS+ Bank of Estonia	National Bank of Georgia +WDI	BIS+WDI	BIS+ National Bank of Kazakhstan +WDI	BIS+ Bank of Latvia	BIS+ Bank of Lithuania	National Bank of Macedonia +WDI	BIS+WDI	BIS+ National Bank of Poland +WDI	National Bank of Romania +WDI	BIS+WDI	BIS+ National Bank of Slovakia +WDI	BIS+ CB of Turkey	BIS+WDI

External debt	WDI	BIS+ WDI	WDI	BIS+ National Bank of Belarus	Bulgarian National Bank + WDI	BIS+ Croatian National Bank+ WDI	BIS	BIS+ Bank of Estonia	National Bank of Georgia + WDI	BIS+WDI	BIS+ National Bank of Kazakhstan + WDI	BIS+ Bank of Latvia +WDI	BIS+ Bank of Lithuania	National Bank of Macedonia +WDI	BIS+ National Bank of Moldova +WDI	BIS+ National Bank of Poland +WDI	National Bank of Romania +WDI	BIS+WDI	BIS+ National Bank of Slovakia +WDI	BIS+ CB of Turkey	BIS+WDI
Fiscal deficit	Albania Stat. Service	Ministry of Finance	CB of Azerbaijan	IFS	IFS	IFS	IFS	Estonia Stat. Service	IFS	Hungary Stat. Service	IFS	IFS	IFS	-	-	IFS	IFS	IFS	Slovak Stat. Service	CB of Turkey	Ukraine Stat. Service
Terms of trade	-	CBA	-	-	Bulgarian National Bank	-	Czech National Bank	-	-	IFS	-	Bank of Latvia	Bank of Lithuania	-	-	IFS	-	-	-	IFS	-
Asset price index or real estate prices	-	-	-	-	IFS	IFS	IFS	IFS	-	IFS	Kazakhstan Stock Exchange	IFS	IFS	-	-	IFS	Eurostat	IFS	IFS	IFS	IFS
Foreign currency deposits	Bank of Albania	UNISIS	CB of Azerbaijan + IMF Country Reports	National Bank of Belarus	Bulgarian National Bank	Croatian National Bank	Czech National Bank	Bank of Estonia	National Bank of Georgia	CB of Hungary + IMF Country Report	National Bank of Kazakhstan	Bank of Latvia	Bank of Lithuania	National Bank of Macedonia	National Bank of Moldova	National Bank of Poland	National Bank of Romania	CB of Russia	National Bank of Slovakia	CB of Turkey	National Bank of Ukraine
Economic growth	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
World economic growth	OECD	OECD	OECD	OECD	OECD	OECD	OECD	OECD	OECD	OECD	OECD	OECD	OECD	OECD	OECD	OECD	OECD	OECD	OECD	OECD	OECD
International oil prices	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS	IFS
Democracy of political system	*Center of International Development and Conflict Management, Polity IV dataset, Polity 2 variable*																				
Elections	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*	*DPI*
Currency regime	AREAER+ Bubul (2002)	AREAER+ Bubula (2002)	AREAER+ Bubul(2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)	AREAER+ Bubul (2002)

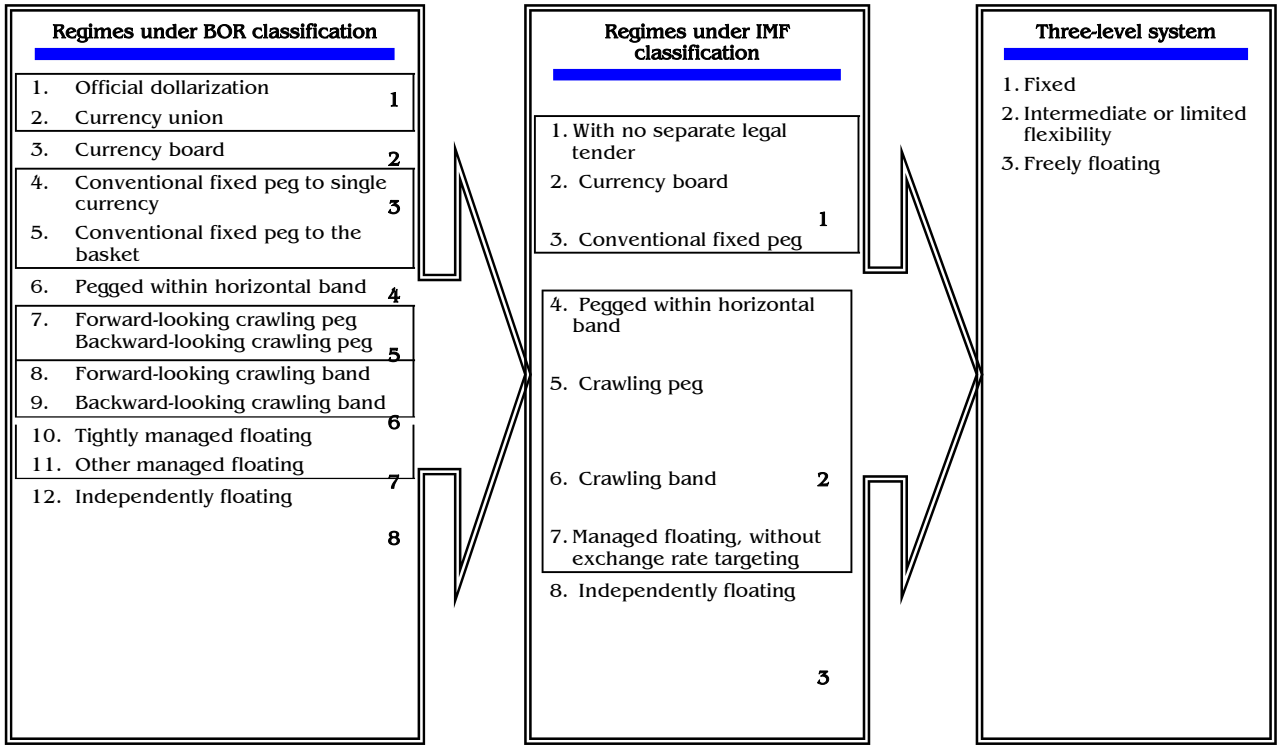
Table DA-2: **Data descriptors and respective modifications**

	Description	Modification
Nominal exchange rate (average monthly)		-
Nominal exchange rate (average quarterly)		-
Nominal exchange rate (end period)		-
International reserves	Total Reserves minus Gold	-
CBA net foreign assets	*CB net foreign assets less Privatization Account*	-
Banks' corresponding accounts in foreign currency	*Banks' corresponding accounts at CB in foreign currency*	Expressed in US dollar, period-end exchange rate
Money Market Rate	Money Market Rate	Albania, Azerbaijan, Hungary, Kazakhstan: treasury bonds interest rates; Belarus, Macedonia: bank refinancing rate
Federal Funds (effective) rate	*Federal Funds (effective) rate*	-
Lending Rate	Lending Rate	-
Inflation	Annualized (y/y) inflation	-
Export	Export FOB	-
Broad money, M2	Broad money, M2	The beginning of Moldova and Ukraine series is interpolated from the yearly series by the Cubic Line Last Match method
Domestic credit	Domestic Credit	-
Deposits	Demand, Time, Savings, Foreign Currency Deposits	-
Banks' foreign assets	Banks' foreign assets	-
Banks' foreign liabilities	Banks' foreign liabilities	-
Real exchange rate	Real effective exchange rate	The beginning of Azerbaijan series is interpolated from yearly series by the Quadratic Average method
Nominal GDP		Series adjusted seasonally; yearly data for some countries (Albania, Azerbaijan, Macedonia, Moldova) converted into quarterly by the Quadratic Sum method, and were not seasonally adjusted
Current account	Current account	-
Remittances	Remittances through the banking system (monthly), From Balance of Payments: Current transfers + Income (quarterly)	-
Short-term external debt	Short-term external debt of all the sectors of the economy	Yearly parts of series of all countries are interpolated by the Cubic Line method
External debt	External debt of government, banks, private and other sectors	Yearly parts of series of all countries are interpolated by the Cubic Line method
Fiscal deficit	Central Government budget deficit	Seasonally adjusted by the X11 Additive method
Terms of trade	Terms of trade index (1997=100)	-
Asset Price index or real estate prices	Stock indices; For Armenia the average price per sq. m. of real estate in Yerevan is used	-
Foreign currency deposits	Time and demand deposits in foreign currency	The beginning of Azerbaijan series is interpolated from yearly series by the Cubic Line method
Economic growth		Yearly data were not interpolated but were attributed to the 4th quarter; indicators of the other quarters were calculated by the use of interpolated series of nominal GDP and GDP deflators or CPI
World economic growth	OECD economic growth index	-
International oil prices	UK Brent oil price	-
Democracy of the political system	Center of International Development and Conflict Management Polity IV dataset, Polity 2 variable, yearly figures	Yearly indices were attributed to the quarters of the particular year, taking into account the date on which the index has been assigned
Elections	Database of Political Institutions (DPI): legelec and exelec series	-
Currency regime	From AREAER report with 3 levels of classification	See *Figure DA-1*

Exchange rate regimes

Of a great diversity of classifications for currency regimes, BOR and IMF classifications[89] were chosen, taking into account close correlation between these two as well as the appropriateness of using the IMF classifications for analytical purposes. For the 1990-2001 BOR classification and for 2002-2008 IMF classification. However, because these two systems use different groupings of classification, we had to match them with each other. Thus form BOR classification (13 regimes) we passed to the IMF classification (8 regimes), and then build a three-level classification system (see Figure DA-1).

Figure DA-1: Matching of the two regime classifications



The yearly series built by the help of the above figure were converted into quarterly series, taking into account the date of regime assignment (normally as of April or December).

Table DA-3: Variables chosen

Variable	Descriptor	Variable	Descriptor
International reserves / GDP	percent	Remittance growth rate (y/y)	percent
Short-term External debt / International reserves	percent	Banks' foreign assets / foreign liabilities	percent
External debt / GDP	percent	Change in terms of trade (q/q)	percent
Real exchange rate overvaluation	percent	Political democracy	index
Current account / GDP	percent	Elections	index
Export growth rate (y/y)	percent	Credit/Deposits	percent
Domestic credit growth rate (y/y)	percent	International oil prices (US dollar)	absolute value
M2 / International Reserves	percent	Difference in short-term and long-term interest rates	percent
Inflation (y/y)	percent	World economic growth (OECD growth, y/y)	percent
Economic growth (y/y)	percent	Exchange rate regime (3-level)	ratio
Changes in asset prices (q /q)	percent	Dollarization	percent
Budget deficit / GDP	percent	Contagion effect	index: binary dummy variable

[89] *Source: BOR classification: Bubula, Otker-Robe (2002), pp. 31-35, Appendix I; IMF classification: AREAER 2002, 2003, 2004, 2005, 2006, 2007, 2008.*

Table DA-4: Datasets used in the main models, by country

Country	*Data*	*Country*	*Data*
Azerbaijan	Q1, 1996 – Q2, 2008	Hungary	Q1, 1990 – Q2, 2008
Albania	Q1, 1994 – Q2, 2008	Kazakhstan	Q1, 1995 – Q2, 2008
Belarus	Q1, 1995 – Q2, 2008	Macedonia	Q1, 1994 – Q2, 2008
Bulgaria	Q1, 1993 – Q2, 2008	Moldova	Q1, 1996 – Q2, 2008
Estonia	Q1, 1993 – Q2, 2008	Czech Republic	Q1, 1993 – Q2, 2008
Turkey	Q1, 1990 – Q2, 2008	Romania	Q1, 1994 – Q2, 2008
Latvia	Q1, 1990 – Q2, 2008	Russia	Q1, 1995 – Q2, 2008
Poland	Q1, 1990 – Q2, 2008	Slovakia	Q1, 1999 – Q2, 2008
Lithuania	Q1, 1993 – Q2, 2008	Georgia	Q1, 1995 – Q2, 2008
Croatia	Q1, 1993 – Q2, 2008	Ukraine	Q1, 1996 – Q2, 2008
Armenia	*Q1, 1996 – Q2, 2008*		

Table DA-5: Existing data points on individual leading indicators, by country

	Albania	*Armenia*	*Azerbaijan*	*Belarus*	*Bulgaria*	*Croatia*	*Czech Rep.*	*Estonia*	*Georgia*	*Greece*	*Kazakhstan*	*Latvia*	*Lithuania*	*Macedonia*	*Moldova*	*Poland*	*Romania*	*Russia*	*Slovakia*	*Turkey*	*Ukraine*
Currency market pressure index	1994 III- 2008 IV	1997I- 2009I	1997 I-2008 IV	1996 I-2009 I	1994 I-2008 IV	1993 I-2008 IV	1994 I-2008 IV	1994 I-2008 IV	1996 I-2008 III	1990 I-2008 IV	1995 I-2009 I	1994 I-2008 IV	1994 I-2008 IV	1994 I-2008 IV	1997 I-2009 I	1991 I-2008 IV	1995 I-2008 IV	1996 I-2008 IV	2000 I-2008 IV	1990 I-2008 IV	1997 I-2008 IV
International reserves/GDP	1993 III-2007 IV	1994 IV-2008 II	1996 III-2007 IV	1994 IV-2008 II	1994 IV-2008 II	1997 IV-2008 II	1993 I-2008 II	1993 IV-2008 II	1996 IV-2008 II	1995 IV-2008 II	1994 IV-2007 IV	1993 III-2008 II	1993 IV-2008 II	1994 III-2006 IV	1996 III-2008 II	1995 IV-2008 II	1997 IV-2008 II	1994 II-2008 II	1993 IV-2008 II	1990 IV-2008 II	2000 IV-2008 II
Short-term external debt/International reserves	1997 IV-2006 IV	1993 IV-2008 II	1993 IV-2006 IV	1994 IV-2008 II	1991 IV-2008 II	1993 IV-2008 II	1999 IV-2008 II	1996 I-2008 II	1995 IV-2008 II	1990 IV-2008 II	1993 IV-2008 II	1993 III-2008 II	1992 IV-2008 II	1993 IV-2008 II	1993 I-2008 II	1990 IV-2008 II	1990 IV-2008 II	1993 IV-2008 II	1993 IV-2008 II	1990 I-2008 II	1992 IV-2008 II
External debt/GDP	1992 I-2006 IV	1994 IV-2008 II	1996 III-2006 IV	1993 IV-2008 II	1994 IV-2008 II	1997 IV-2008 II	1999 IV-2008 II	1996 I-2008 II	1996 IV-2008 II	1995 IV-2008 II	1994 IV-2007 IV	1992 IV-2008 II	1993 IV-2008 II	1994 III-2006 IV	1996 III-2008 II	1995 IV-2008 II	1997 IV-2008 II	1994 II-2008 II	1993 IV-2008 II	1990 IV-2008 II	2000 IV-2008 II
Real exchange rate overvaluation	-	1997 I-2008 II	2000 IV-2008 II	1996 I-2008 II	1992 I-2008 II	1992 I-2008 II	1990 I-2008 II	1994 I-2008 II	1993 IV-2008 II	1990 I-2008 II	2000 I-2008 II	1994 I-2008 II	1994 I-2008 II	1992 I-2008 II	1994 I-2008 II	1990 I-2008 II	1990 I-2008 II	1994 I-2008 II	1990 I-2008 II	1994 I-2008 II	1992 I-2008 II
Current account/GDP	1993 I-2007 IV	1994 IV-2008 II	1999 I-2007 IV	1996 I-2008 II	1994 I-2008 II	1997 I-2008 II	1993 I-2008 II	1993 I-2008 II	1996 I-2008 II	1995 I-2008 II	1995 I-2007 IV	1993 I-2008 II	1993 I-2008 II	1994 I-2006 IV	1995 IV-2008 II	2000 I-2008 II	1997 I-2008 II	1994 I-2008 II	1993 I-2000 IV, 2001 I-2007 IV	1990 I-2008 II	2000 I-2008 II
Export growth rate (y/y)	1995 I-2008 II	1994 I-2008 II	1999 I-1995 IV, 1999 I-2008II	1995 I-2008 II	1992 I-2008 II	1991 I-2008 II	1994 I-2008 II	1993 III-2008 II	1996 I-2008 II	1994 I-2008 II	1994 III-2008 I	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1995 I-2008 II	1991 I-2008 II	1991 I-2008 II	1993 I-2008 II	1994 I-2008 II	1991 I-2008 II	1994 I-2008 II

Credit/Deposits	Elections	Political democracy	Change in terms of trade (q/q)	Banks' foreign assets / foreign liabilities	Remittance growth rate (y/y)	Budget deficit/GDP	Change in asset price (q/q)	Economic growth (y/y)	Inflation (y/y)	M2/International reserves	Domestic credit growth rate (y/y)	
1994 IV-2008 II	1990 I-2008 II	1990 I-2007 IV	1990 II-2008 II*	1994 IV-2008 II	1996 I-2007 IV	1998 I-2007 IV	-	1991 IV-2007 IV	1992 I-2008 II	1993 IV-2008 II	1995 IV-2008 II	***Albania***
1992 IV-2008 II	1990 I-2008 II	1991 III-2007 IV	1997 II-2008 II	1992 IV-2008 II	1994 II-2008 II	1997 I-2008 II	2002 II-2008 II	1996 I-2008 II	1994 I-2008 II	1995 I-2008 II	1993 IV-2008 II	***Armenia***
1992 IV-2008 II	1990 I-2008 II	1991 IV-2007 IV	-	1992 IV-2008 II	2000 I-2008 II	2001 II-2007 IV	-	1996 IV-2007 IV	1992 I-2008 II	1995 IV-2008 II	1993 IV-2008 II	***Azerbaijan***
1994 IV-2008 II	1990 I-2008 II	1991 IV-2007 IV	-	1994 IV-2008 II	1997 I-2008 II	1998 I-2002 IV, 2007 I-2007 IV	-	1993 I-2008 II	1993 I-2008 II	1999 IV-2008 II	1995 IV-2008 II	***Belarus***
1991 IV-2008 II	1990 I-2008 II	1990 I-2007 IV	2001 I-2008 II	1991 IV-2008 II	1992 I-2008 II	1994 I-2008 II	2001 I-2008 II	1995 I-2008 II	1991 I-2008 II	1995 IV-2008 II	1992 IV-2008 II	***Bulgaria***
1994 II-2008 II	1990 I-2008 II	1991 II-2007 IV	1990 II-2008 II*	1994 II-2008 II	1994 I-2008 II	1997 I-2008 II	1997 IV-2008 II	1994 I-2008 II	1993 I-2008 II	1993 IV-2008 II	1995 II-2008 II	***Croatia***
1993 I-2008 II	1990 I-2008 II	1990 I-2007 IV	1993 II-2008 II	1993 I-2008 II	1994 I-2008 II	1993 I-2007 II	1998 I-2008 II	1995 I-2008 II	1994 I-2008 II	2002 I-2008 II	1994 I-2008 II	***Czech Rep.***
1991 IV-2008 II	1990 I-2008 II	1991 IV-2007 IV	-	1991 IV-2008 II	1993 I-2008 II	1999 I-2008 II	1996 IV-2008 II	1994 I-2008 II	1993 I-2008 II	1993 I-2008 II	1992 IV-2008 II	***Estonia***
1995 IV-2008 II	1990 I-2008 II	1991 IV-2007 IV	-	1995 IV-2008 II	1998 I-2008 I	2006 I-2008 II	-	1997 I-2008 II	1995 I-2008 II	1995 I-2008 II	1996 IV-2008 II	***Georgia***
1990 I-2008 II	1990 I-2008 II	1990 I-2007 IV	1990 II-2008 II	1990 I-2008 II	1991 I-2008 I	1996 I-2008 II	2000 II-2008 II	1996 I-2008 II	1990 I-2008 II	1990 IV-2008 II	1991 I-2008 II	***Greece***
1997 I-2008 II	1990 I-2008 II	1991 IV-2007 IV	-	1993 IV-2008 II	1996 I-2008 II	1999 I-2007 IV	2000 IV-2008 II	1995 I-2007 IV	1994 I-2008 II	1993 IV-2008 II	1994 IV-2008 II	***Kazakhstan***
1993 III-2008 II	1990 I-2008 II	1991 III-2007 IV	1998 II-2008 II	1993 III-2008 II	1994 I-2008 II	1996 I-2008 II	1996 III-2008 II	1991 I-2008 II	1992 I-2008 II	2003 I-2008 II	1994 III-2008 II	***Latvia***
1993 I-2008 II	1990 I-2008 II	1991 III-2007 IV	2006 II-2008 II	1993 I-2008 II	1994 I-2008 II	1999 I-2008 II	2001 I-2008 II	1994 I-2008 II	1993 I-2008 II	1993 IV-2008 II	1994 I-2008 II	***Lithuania***
1993 IV-2008 II	1990 I-2008 II	1991 III-2007 IV	1990 II-2008 II*	1993 IV-2008 II	1991 I-2007 IV	-	-	1994 IV-2006 IV	1994 I-2008 II	2003 I-2008 II	1994 IV-2008 II	***Macedonia***
1991 IV-2008 II	1990 I-2008 II	1991 III-2007 IV	-	1992 I-2008 II	1995 I-2008 II	-	-	1996 IV-2008 II	1995 I-2008 II	1993 IV-2008 II	1992 IV-2008 II	***Moldova***
1990 I-2008 II	1990 I-2008 II	1990 I-2007 IV	1990 II-2008 II	1990 I-2008 II	1991 I-1995 II, 2001 I-2008 I	1996 I-2008 II	1993 II-2008 II	1996 I-2008 II	1990 I-2008 II	1996 IV-2008 II	1991 I-2008 II	***Poland***
1990 I-2008 II	1990 I-2008 II	1990 I-2007 IV	1990 II-2008 II*	1990 I-2008 II	1992 I-2008 II	2001 I-2006 IV	2001 I-2008 II	1999 I-2008 II	1991 I-2008 II	2001 IV-2008 II	1991 I-2008 II	***Romania***
1993 IV-2008 II	1990 I-2008 II	1992 I-2007 IV	1990 II-2005 IV**	1993 IV-2008 II	1995 I-2008 II	1994 II-2008 II	1996 I-2008 II	1996 I-2008 II	1993 I-2008 II	1995 II-2008 II	1994 IV-2008 II	***Russia***
1993 I-2008 II	1990 I-2008 II	1993 I-2007 IV	1990 II-2008 II*	1993 I-2008 II	1994 I-2000 IV, 2003 I-2007 IV	1993 I-2008 II	2000 II-2008 II	1994 I-2008 II	1994 I-2008 II	2000 IV-2008 II	1994 I-2008 II	***Slovakia***
1990 I-2008 II	1990 I-2008 II	1990 IV-2007 IV	1990 II-2008 II	1990 I-2008 II	1991 I-2008 II	2006 I-2008 II	1990 I-2008 II	1991 I-2008 II	1990 I-2008 II	1990 I-2008 II	1991 I-2008 II	***Turkey***
1992 IV-2008 II	1990 I-2008 II	1991 IV-2007 IV	-	1992 IV-2008 II	1995 I-2008 II	2002 I-2007 IV	1998 I-2008 II	2001 I-2008 II	1993 I-2008 II	1992 IV-2008 II	1993 IV-2008 II	***Ukraine***

	Albania	Armenia	Azerbaijan	Belarus	Bulgaria	Croatia	Czech Rep.	Estonia	Georgia	Greece	Kazakhstan	Latvia	Lithuania	Macedonia	Moldova	Poland	Romania	Russia	Slovakia	Turkey	Ukraine
International oil price (US dollar)	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II	1994 I-2008 II
Difference in short-term and long-term interest rates	1994 III-1997 III, 1999 I-2008 II	1995 IV-2008 II	1999 I-2008 II	1992 IV-2008 II	1990 IV-2008 II	1992 I-2008 II	1993 I-2008 II	1993 IV-2008 II	1995 III-2007 IV	1990 I-2008 II	-	1993 IV-2008 II	1994 I-2008 II	1994 I-2008 II	1996 II-2008 II	1991 I-2006 IV	1995 I-2008 II	1994 III-2008 II	2000 I-2008 II	-	1996 IV-2008 II
World economic growth (OECD country growth y/y)	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II	1997 I-2008 II
Currency regime (3-level)	1991 I-2008 II	1992 I-2008 II	1992 I-2008 II	1992 I-2008 II	1990 I-2008 II	1992 I-2008 II	1990 I-2008 II	1992 I-2008 II	1992 I-2008 II	1990 I-2008 II	1992 I-2008 II	1992 I-2008 II	1992 I-2008 II	1992 I-2008 II	1992 I-2008 II	1990 I-2008 II	1990 I-2008 II	1992 I-2008 II	1993 I-2008 II	1990 I-2008 II	1992 I-2008 II
Dollarization	1994 IV-2008 II	1995 I-2008 II	1995 IV-2000 IV, 2002 IV-2008 II	2000 I-2008 II	1995 IV-2008 II	1994 II-2008 II	1993 I-2008 II	1993 I-2008 II	1995 IV-2008 II	1997 I-2008 II	1997 IV-2008 II	1994 I-2008 II	1993 IV-2008 II	1997 I-2008 II	1999 IV-2008 II	1996 IV-2008 II	1994 I-2008 II	1998 I-2008 II	2005 I-2008 II	1990 I-2008 II	1996 IV-2008 II
Contagion effect	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II	1990 II-2008 II

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Economic growth	The growth of volume of goods and services produced in the economy during a certain period of time.
Inflation	An increase in the general level of prices of goods and services.
Consumer price index	An index of the variation in prices paid by typical consumers for retail goods and other items. The consumer price index measures the changes in the price of a market basket of consumer goods and services purchased by households.
Balance of payments	A system of recording of all economic transactions of Armenia (residents and non-residents) with the rest of the world over a reporting period (a quarter, a year).
Foreign trade	This involves an exchange of capital, goods, and services across international borders or territories, in the form of exports and imports.
Gross external debt	Gross external debt, at any given time, is the outstanding amount of those actual current, and not contingent, liabilities that require payment(s) of principal and/or interest by the debtor at some point(s) in the future and that are owed to nonresidents by residents of an economy.
Credit risk	Credit risk refers to the risk that a borrower will default on any type of debt by failing to make payments which it is obligated to do. The risk is primarily that of the lender and includes the lost principal and interest, disruption to cash flows and increased collection costs.
Liquidity risk	Liquidity risk is the risk that a given security or asset cannot be traded by the financial institution quickly enough in the market to prevent a loss (or make the required profit).
Foreign currency risk	Foreign currency risk is the risk that a change in exchange rate in the market will adversely affect profits and/or capital of the financial institution.
Interest rate risk	Interest rate risk is the risk that interest rate volatilities in the market will adversely affect profits and/or capital of the financial institution.
Price risk	Price risk is the risk that a change in price of securities in the market or price of similar financial instruments on balance sheets will adversely affect profits and/or capital of the financial institution.
Standard asset	An asset which is serviced under a contract, and is not problematic.
Watched asset	An asset which is serviced under an original contract yet certain circumstances have emerged that may undermine the borrower's ability to serve that asset.
Substandard asset	An asset the contractual obligations towards which are not performed due to the borrower's fragile financial standing or inability to repay the debt.
Doubtful asset	An asset the contractual obligations towards which are not performed; it is more problematic, making its collection at the given time very difficult or impossible.
Bad asset	An asset non-collectable and fully impaired uncollectible, so that its recording on the balance sheet is no longer reasonable.
Nonperforming asset	An asset which has been classified by the bank as watched or substandard or doubtful or bad.
Major borrower	A party the risk on which exceeds 5 percent of total capital of the bank.

Major liability	A liability that amounts to 5 percent and more of total liabilities of the financial institution, without regard to affiliation.
Return on assets (RoA)	A ratio of net annual profit to average annual total assets.
Return on equity (RoE)	A ratio of net annual profit to average annual total capital.
Total liquidity	A ratio of high liquid assets to total assets.
Current liquidity	A ratio of high liquid assets to demand liabilities.
Regulatory total capital	The difference between total capital as shown in statement on financial standing and deductions as specified in Central Bank "Regulation 2 on Banks and Banking".
Capital adequacy	A ratio of regulatory total capital to risk weighted assets.
Leverage	A ratio of total assets to total capital.
Off-balance sheet contingent asset	Off-balance sheet contingent assets include outstanding credit lines, credit cards and overdrafts as well as letters of credit, guarantees and warranties provided.
Net provisioning	The difference between provisions to and recoveries from assets loss reserve fund.
Net foreign currency position	The difference between assets and liabilities in FX assets and local currency assets containing FX risk.
Gross foreign currency position	This position measures the sum of absolute values of positions of various currencies.
The Herfindahl-Hirschman index	This index is defined as the sum of the squares of the market shares. It varies between 0 and 1, characterizing the level of concentration (values near to 0 denote lower concentration.
Economic cost of capital	The difference of the present value of total assets and present value of total liabilities.

ABBREVIATIONS

CBA	Central Bank of the Republic of Armenia
GDP	Gross Domestic Product
GNDI	Gross National Disposable Income
NSS	National Statistics Service
IMF	International Monetary Fund
UNO	United Nations Organization
CIS	Commonwealth of Independent States
ECB	European Central Bank
USA	United States of America
FRS	Federal Reserve System
NMC	National Mortgage Company
FDI	Foreign Direct Investment
RF	Russian Federation
IFRS	International Financial Reporting Standards
MTPL	Motor third party liability insurance
CDA	Central Depositary of Armenia
TB	Treasury Bills
EPS	Electronic Payments System

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