Early Warning Systems for Currency Crises

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Abstract: *Currency crises may appear and propagate under many forms, a fact which led to their analysis through various methods. In a meta-analysis, a couple of authors (Frankel and Saravelos) review more than 80 papers of the literature on early warning systems for currency crises in which they found out that low central banks' reserves is the most reliable warning indicator. There are indicators such as "Exchange Market Pressure Index (EMPI) developed by Girton and Roper which is used to quantify pressures on a currency. This indicator is relevant whether the exchange rate is flexible, fixed, or intermediate". In case of currency risk in Africa, "the EMPI is calculated monthly as a weighted sum of both the annual change in the exchange rate against the US dollar, and the change in reserves. As such, it can be either positive or negative. A higher EMPI - indicating a depreciation and/or depletion of reserves- reflects increased tensions in the foreign exchange market". The need to predict systemic crises has led to the creation of a monitoring instrument known as the early warning system - EWS. The early warning system used for currency crises makes it possible to predict the appearance of a crisis within a well-defined period of time. Such a method may be applied both for currency crises, as well as for banking or fiscal ones. This method consists in the analysis of economic and financial indicators that facilitate the collection of information related to the potential vulnerability of the payment balance or to the non-sustainability of the exchange rate.*

Keywords: early warning system (EWS); signal-based approach; methods of a logit/probit type; methods used for analysing the impact of a currency crisis; currency market pressure indicators, currency crisis indicators etc.

1. Introduction

The present paper deals with currency crisis warning methods, as well as with preventing currency crisis methods. In devising the EWS, several methods are used; the most important ones are as follows:

a) methods based on a signal-based approach, consisting in monitoring a set of indicators: if these methods surpass a certain threshold, which was previously calculated, this is considered to be a warning signal. Indicators can be: calculated indicators – composite indicators of vulnerability (currency market pressure indicators, banking system stability indicators (sentiment indicators): GDP increase, budgetary deficit, capital market indices, securities spread (Kaminsky, Lizado and Reinhart) [1];

b) logit/probit type methods (limited dependent variable - LDV): they estimate an econometric model of a logit/probit type wherein the depending variable indicating the appearance of a crisis is calculated on the basis of the currency market pressure indicator, whereas explaining variables are economic and financial indicators. The model has the advantage that it allows to measure the effect of each explaining variable over the crisis probability (Frankel and Rose, 1997 or Bussiere and Fratzscher, 2002)[2],

c) model for analysing the impact of a currency crisis (severity of crises indicators): this model determines which countries will be most seriously affected if a financial external crisis bursts out in a country from a certain region. The method is used to define a crisis indicator over a period and during a stress period for international financial markets – the differences incurred by the index for every country are explained by the variables that describe economic conditions of the analysed crisis (Sachs, Tornell and Velasco, 1996)[3]. The first two of the methods enumerated above are going to be presented in the next lines.

2. Literature Review

1. Methods relying on a signal-based approach

Signal-based approach methods have been considerably developed in a set of works by Kaminsky, Lizondo and Reinhart (1996, 1998)[4], whose methodology will be used in the next lines. We should point out that, in calculating some indicators, depending on the existing data, a larger sample of countries has been used in comparison with the second model (Argentina, Brazil, Bulgaria, the Czech Republic, Chile, Columbia, South Korea, Croatia, Estonia, Philippines, Indonesia, Latonia, Lithuania, Malaysia, Mexico, Poland, Romania, Russia, Slovakia, Slovenia, Thailand, Turkey, Hungary, Venezuela):

In this context, the crisis is defined as the period in which the currency pressure indicator surpasses the average value and it surpasses two times and a half the standard difference. The currency pressure indicator is a moderate sum of three factors: the increase rate of the real exchange course and the increase rate of the international reserves.

An indicator issues a signal when it surpasses a certain percentile in the distribution of the values of that indicator[1] (here we have chosen 15 %, and 85 %, depending on the indicator). One should mention that these limits are specific to each country, in the sense that, even if the percentiles are identical for all countries, the value of the signal-based indicator varies depending on the country.

The analysis may be synthetized as in the matrix comprised in Table 1. The signalling period was chosen *a priori* as lasting 12 month. Thus, if the chosen indicator issues a signal followed by a crisis 12 months before the crisis starts, this is a good signal; if the signal is not followed by a crisis then the signal is a false one.

Analysis of the signal issued depending on the identified crisis period Table 1

	Crisis in the next 12 months	No crisis in the next 12 months
Signalling a crisis	A	B
Non-signalling a crisis	C	D

The results of the analysis relying on this method are presented in Table 2 .

Performance of indicators when using the signal-based model Table 2

No.	Indicators	Issued signals	Correct signals Total number of potentially correct signals A(A+C)	False signals Total number of potentially false signals B(B+D)	Noise to signal ratio [NS/ (B/(B+D)] / [A/(A+C)]	Conditioned probability (crisis/signal) A/(A+B)	Unconditional crisis probability (A+C) /'(A+B+C+D)	Persistence degree of a signal (crisis VS normal period) 1/NS
0	1	2	3	4	5	6	7	8
1	M2/Reserves	527	0.44	0.12	0.28	0.20	0.07	3.55
2	Overestimation of the real currency exchange rate	440	0.45	0.14	0.31	0.17	0.06	3.25
3	Short-term debt / total debt	487	0.38	0.14	0.36	0.16	0.06	2.75
4	Private debt/GDP	455	0.22	0.10	0.47	0.11	0.06	2.14
5	Total debt/GDP	456	0.22	0.11	0.48	0.11	0.06	2.07
6	Current account/GDP	548	0.35	0.18	0.53	0.10	0.06	1.90
7	Portfolio investments/GDP	406	0.24	0.15	0.62	0.09	0.06	1.61
8	Short-term debt/ Exports	481	0.22	0.14	0.62	0.10	0.06	1.61

[1] E,g, for the increase of the non-governmental credit we used the superior perception of the distribution (85 %), while for the current account / GDP we used the inferior percentile (15 %).

9	Export increase	489	0.19	0.14	0.71	0.09	0.06	1.40
10	Budgetary deficit	434	0.25	0.18	0.73	0.09	0.07	1.37
11	Non-governmental credit /GDP	473	0.17	0.14	0.84	0.07	0.06	1.19
12	ISD/GDP	2153	0,.7	0.85	1.10	0.05	0.05	0.91
13	Public debt/GDP	445	0.12	0.13	1.12	0.05	0.06	0.89
14	ISD/Total debt	2318	0.76	0.86	1.14	0.05	0.06	0.88
15	Exports/GDP	2457	0.60	0.80	1.32	0.05	0.06	0.76
16	Increase in the real GDP	455	0.10	0.17	1.66	0.04	0.06	0.6
17	Degree of opening	722	0.04	0.24	5.60	0.01	0.06	0.18

Column 3 indicates the share of correctly signalled crises in relation to the total number of crisis signals that could have been sent correctly. According to Kaminsky (1998), 100 % indicates that there is a crisis signal for each of the 12 months preceding the crisis. One can notice that the share of direct foreign investments expressed in relation to the GDP (ISD/GDP), followed by the share of direct foreign investments expressed in relation to the total debt (ISD/total debt) and the share of exports expressed in relation to the GDP (exports/GDP) poses the highest percentage of good signals. However, one has to be very cautious when interpreting these signals. Column 4 indicates the number of false signals expressed as a percentage of the total potential of false signals that could have been sent. One can notice that the previously mentioned variables (ISD/GDP, ISD/total debt, exports/GDP) have recorded a high degree of false signals. The first three of them, for which there is a low percentage of false signals expressed in relation to all the sent signals, are: private debt/GDP, total debt/GDP and M2/reserves.

In order to simultaneously measure the ability of an indicator to send good and false signals, Kaminsky et. al. (1998) suggest using what they call noise to signal ratio defined as a fraction illustrating the relationship between signalling an unfulfilled crisis and the periods without crisis B/(B+D) and the relationship between signalling a real crisis and the periods of crisis A/(A+C). This is illustrated in column 5 of Table 2. For an indicator which sends signals at random and for a sufficiently large sample, the law of large numbers implies a noise to signal ratio that is equal to 1. Thus, those indicators that point noise to a signal ratio higher than 1 have an extremely low power to signal crises. In the present context, they are: ISD/GDP, public debt/GDP, exports/GDP, real GDP growth, opening degree (calculated as a relation between the sum of exports and imports and the GDP) and inflation. The high value of the indicators recorded for variables like the growth of the real GDP and inflation, as pointed out by Kaminsky et.al. (1998), predicts crisis relatively well.

The indicators that have a sub-unitary degree of correctly signalling crises and of avoiding false signals are: M2/reserves, overestimation of the real rate, short term debt/total debt, short-term debt/exports, exports growth, governing deficit, non-governmental credit/GDP.

Another aspect pointed out by Kaminsky et.al. (1998) refers to the difference between the probability conditioned by the appearance of the crisis (column 6) and the unconditioned probability (column 7). If that indicator has a high degree of predictability, conditioned probability should be at a relatively higher level than the unconditioned one, a fact which is true for the first 6 indicators. One should notice that, for the used sample, the probabilities record relatively low values, which are, e.g., comparable with the ones estimated by Kaminsky et.al. (1998); the last aspect may be determined by the inclusion in the sample of some countries which, during the investigated period, did not experience major crises, a fact which leads to the mitigation of the conditioned and unconditioned probability.

The last column in the table indicates the degree of persistence for the indicators for the 12 months interval before the crisis and in relation to the other periods. Thus, M2/reserves and the overestimation of the real exchange rate are three times more persisting during the pre-crisis periods in comparison with the ones in which no crises are incurred. A coefficient higher than 2 is also obtained for the 3 indicators that involve different forms of debt in relation to the GDP.

The relatively good performance of the total and private debt expressed in relation to the GDP, and in comparison with the poor result recorded by the total public debt/GDP, may be due to a higher share of the private debt in relation to the total debt for the countries that underwent a currency crisis period and/or a poor quality of the data for these indicators; these facts are reconfirmed by econometric analyses in which these indicators are not relevant when estimating the crisis probability.

Berg et. al. (1998)[5] were some of the first who tested the accuracy of the models (both the ones developed by Kaminsky et.al. in 1998, and the logit/probit ones) during the insample and the out-of-sample periods. To achieve this goal they assess the models using observations made until 1995 and make predictions for the next 2 years. The authors use a threshold of probability of 25 % and 50 % to indicate the appearance of the crisis. The authors compare the results obtained with the real values.

The model of Kaminsky, Reinhart and Lizondo (1998)[6] predicts the observations in a correct manner for 70 % of the cases. However, the prediction of crisis is of interest considering the previous result, which may be due to the prolonged periods in which crises did not occur. Thus, the mentioned model correctly predicts only 34 % of the pre-crisis period, when the threshold is 25 %. At the same time, more than half of the signals are false. Moreover, the crises occurred in 24 % of the cases without being signalled.

In contrast, the logit/probit models have a high degree of predictability. When the threshold is 25 %, the model correctly anticipates 79 % of the observations. 73 % of the precrisis periods were correctly predicted and the proportion of false alarms is a little below 50 %. In order to surpass a series of shortcoming specific to the above mentioned models, a LDV model was used, which was based on a logit multinomial procedure.

2. Limited dependent variable - logit multinomial methods

This model belongs to the category which is based on variables of a qualitative nature, but, in this case, the explained variable is not binary. The used econometric instrument is a logit multinomial model. In comparison with a binary model, the crisis period is split into two parts: the pre-crisis period and the crisis period and post-crisis period. This separation allows avoiding the post-crises bias effect, which records different evolutions for the macroeconomic indicators during the two periods (Bussiere and Fratzscher, 2002)[7].

The creation of a warning model based on a logit multinomial model involves the following stages:

calculating a pressure indicator for the currency market: this allows defining the crisis period, including not only the successful attacks on a currency (forcing the central bank to give up a fixed regime), but also the external vulnerability moments in which the measures taken by the monetary authority or the favourable external situation of the country made it possible to avoid a currency crisis;

calculating the indicator of currency crisis;

calculating the crisis indicator (the multinomial indicator);

estimating the model by the econometric logit multinomial method;

determining the optimum threshold for signalling a currency crisis.

On the basis of the crisis indicator the logit multinomial model is created. Explanatory variables are the ones which may depict the external financial and economic situation of a country.

The main variables used in the model were (a selection criterion that we used was the signal-based analysis, as described before) [8]:

external competitiveness indicators: overestimation of the exchange rate, current account, commercial balance, imports/exports – at an absolute level and as a growth rhythm. The use of the real effective rate instead of the real rate is motivated by the necessity of identifying external competitiveness issues and it allows for fixed-rate savings to be evaluated;

external exposure: short-term debt/reserves, total debt/reserves, growth rhythm of debt on a short-term;

internal economic indicators: the growth of the real GDP, budgetary deficit, inflation rate;

financial indicators: non-governmental credit, governmental credit, currency multiplicator, M2/GDP, volume of banking deposits;

contagion indicators: contagion and the banking system.

Calculating the contagion indicator of the banking system was used through the method proposed by Fratzscher (2000)[9]:

$$CB_{ij} = \sum \left(\frac{F_{dj} \cdot F_{di}}{F_d \cdot F_i} \right) \qquad (1)$$

where F_{dj} represents credits which were granted by country "d", and F_d stands for the

total number of credits which were granted by country "d".

In the present analysis, countries marked with "d" are developed economies, whereas countries marked with i,j(iF) are emerging economies. The interpretation of this indicator relies on the effect of the common lender (common lender effect): if country "j" faces a currency crisis and the degree to which the "d" country is indebted to the former one is a high one, the probability for country "d" to refuse prolonging the debt or the probability for this country to withdraw the capitals placed in country "i" is also higher.

In order to signal a crisis for the chosen countries and periods we chose an optimal threshold (if a probability surpasses this threshold, the signal indicates a crisis). Thus, the result obtained on the basis of this model corresponds to the situations depicted by using the signal-based method.

Choosing the optimum threshold and period must rely on the number of crises that were not signalled and the number of false alarms, which is regarded as optimum for establishing the currency policy. Let us consider the following cost[10] function:

$$\alpha(T) = \theta \cdot P_{CN}(T) + (1-\theta) \cdot P_{CS}(T) \qquad (2)$$

where T is the probability threshold; P_{CN} is the probability of not signalling a crisis; P_{cs} is the probability of signalling a crisis; Θ the cost of non-signalling a crisis or the degree of aversion to risk.

The increase of the temporal horizon and the probability threshold determine the increase of the number of non-signalled crises but it reduces the number of false alarms.

3. The pressure indicator for the currency market

The pressure indicator for the currency market is calculated as an average sum of three factors: the increase rate of the real exchange rate, the increase of the real interest rate and the increase rate of the international reserves; this is calculated as follows:

$$EMP_{i,t} = \left(\frac{1}{\sigma_e^2}\right) \cdot \left(\frac{\Delta e_{i,t}}{e_{i,t-i}} + \frac{1}{\sigma_r^2}\right) \cdot \left(\frac{\Delta e_{i,t}}{\gamma_{i,t-i}} - \frac{1}{\sigma_{res}^2}\right) \cdot \frac{\Delta res_{i,t}}{res_{i,t-i}} \qquad (3)$$

where σ_e^2 represents the volatility of the exchange rate, σ_r^2 the volatility of the interest rate, σ_{res}^2 the volatility of international reserves.

The motivation for defining the pressure indicator in this manner is that, in the event of a currency attack, the currency authority has two options: either it attempts to maintain the rate (this is the situation of fixed currency regimes) by mitigating reserves and/or the increase of the interest rate or it gives up supporting the rate and then the currency is strongly devalued.

The use of the inverse variation as a weight factor is due to the fact that the factors with a lower volatility are considered to be more important (the most important factor used to determine the crisis is the modification of international reserves). Similarly, the use of a constant weight for all the countries makes the pressure indicator, including the crisis indicator, comparable for all the countries; this is true especially for the economies that use fixed exchange regimes (the volatility of the exchange rate is lower in this case, a fact which granted more weight to the exchange rate).

Some studies (Edison, 2000[11] or Mills and Omarova, 2004[12]) do not include the interest rate when they calculate the pressure indicator; this omission is most of the time motivated by lack of data in emerging countries. Other studies (Berg, Borensztein and Pattilo, 2004[13]) explain the lack of the interest rate data by referring to the fact that the devaluation of the exchange rate and the increase of the interest rate are different events; thus, the use of the interest rate when calculating the pressure indicator would lead to an accrued prediction of the two events.

4. Currency crises indicator

The currency crises indicator defines the crisis period as the moment when the pressure indicator exceeds the average value and it twice exceeds the standard deviation[2].

$$CC_{i,t} = \begin{cases} 1, daca \ldots \overline{EMP_{i,t}} \succ EMP_i + 2\delta EMP_{(i)} \\ 0, in \ldots rest \end{cases} \qquad (4)$$

0, *for...the...rest*

Once the currency crisis periods are defined, one can identify the crises indicator which will be used in the logit multinomial analysis.

The main problem in defining this indicator is the period in which the currency crisis probability is observed. The separation of the two pre-crisis and post-crisis periods may be made in relation to this period. However, the economies that experienced currency crises underwent different periods of recession and recovery. Thus, defining the pre- and post-crisis periods must be a compromise between the analysis horizon (which the authority in charge with maintaining financial stability set) and the period comprised between the first signs of external vulnerability and the currency crisis incurred by the chosen countries and during the analysed period.

The most used periods of time in economic literature comprise 12, 18 and 24 months.

In this analysis, the best results were obtained for the 12 month period.

The crisis indicator is calculated as follows:

$$y_{i,t} = \begin{cases} 1, daca \ \exists k = \overline{1,12} \ldots CC_{i,t+k} = 1 \ldots si \ldots CC_{i,t+1-k} \neq 1 \\ 2, daca \ \exists k = \overline{1,12} \ldots CC_{1,t+1-k} = 1 \\ 0, in \ldots rest \end{cases} \qquad (5)$$

the values of 0.1 and 2 have the following significance:

- y=0, a quiet (normal) period: no currency crisis occurred 12 months before and there is no probability for a new crisis to occur in the next 12 months;
- y=l, the pre-crisis period: a crisis is anticipated for the next 12 months but no crisis occurred before;
- y=2, the post-crisis period: a crisis occurred 12 months before.

5. The results obtained with the econometric model

The logit multinomial analysis was accomplished for 21 emerging economies. Only two emerging countries were used because in these countries domestic and external financial problems are a key factor in the outset of a currency crisis – a fact which does not refer to developed countries. This result was also obtained with the study accomplished by Kaminsky (2003)[2].

The analysed period covers the maximum temporal interval of 1994-2004[3]. The main crises incurred during this period for the chosen countries occurred in: Mexico (1994), the Czech Republic (1997), Bulgaria (1996), Asia (1997)', Russia (1998), Brazil (1999) and Turkey (2000). The results of this econometric model are presented in Table 3.

We used the following indicators:

- overestimation of the national currency (calculated as a real and effective departure from a linear trend);
- GDP; the rhythm with which the non-governmental credit grew as a percentage from the
- the share of the current account deficit of the GDP;
- the relationship between the monetary M2 aggregate and the reserves;
- the rhythm with which exports grew.

[2] For the signal-based model the data referring to the following countries were used: Brazil, Bulgaria, The Czech Republic, Chile, Columbia, South Korea, Croatia, Estonia, Philippines, Latonia, Lithuania, Malaysia, Mexico, Poland, Romania, Russia, Slovakia, Slovenia, Turkey, Hungary, Venezuela.

[3] The period of time established for each country was determined in accordance with the existing data.

The choice of the indicators was also made in relation to the noise-to-signal values, which were calculated previously according to the criterion that indicators whose value is lower than the relation may better explain crises.

The results of the econometric estimation were calculated with the logit multinomial model for the period comprised between: 1994-2004.

Table 3

Multinomial logistic regression					Number of obs.= 2349 LR Chi2(10)= 653.33		
Log likelihood =-973.47669					Prob>Chi2= 0.0000 Pseudo R2= 0.2513		
	Y	coef.	Std.Err.	Z	p»|z|	[95% Coef. Interval]	
y=i	Overestimation	0.1087522	0.00922105	11.81	0.000	0.0907	0.1268043
	NGC/GDP	0.136496	0.0069529	1.96	0.050	0.0000223	0.027277
	CA/GDP	-0.0444268	0.0201994	-2.20	0.028	-0.084017	-0.0048367
	M2/Reserves	0.6886401	0.0707071	9.74	0.000	0.5500568	0.8272235
	Export growth	-0.0082245	0.0048127	-1.71	0.087	-0.0176571	0.0012082
	Constant	-5.675106	0.3016928	-18.81	0.000	-6.266413	-5.083799
y=2	Overestimation	-0.0659354	0.0088901	-7.42	0.000	-0.0833598	-0.0485111
	NGC/GDP	-0.0124348	0.004345	-2.85	0.004	-0.209891	-0.0038805
	CA/GDP	0.0306049	0.0116045	2.64	0.008	0.0078605	0.0533494
	M2/Reserves	0.9095183	0.0647752	14.04	0.000	0.7825613	1.036475
	Export growth	-0.0270937	0.0036976	-7.33	0.000	-0.0343409	-0.0198465
	Constant	-4.59022	0.2282077	-20.11	0.000	-5.037498	-4.142941

(y=0 is the main group)

The first part of Table 3 illustrates the coefficients for the five used variables, while indicating a pre-crisis probability in relation to the probability of experiencing a normal period. The variables are included in the equation with the expected signal. The overestimation of the national currency and the M2/reserves ratio have a significance of 1 %; the increase of the internal credit is related to the GDP increase, the current account deficit related to the GDP amounts at 5 %; the export increase amounts at 10 %.

An increase of the real effective rate in relation to the trend, a lending boom (the increase of the non-governmental credit/GDP), an increase of M2 in relation to reserves all lead to an increase in the crisis probability. Similarly, a high current account deficit and a decrease of the rhythm of export growth indicate an increased crisis probability.

One can notice the difference between the pre- and post- crisis period especially as to the overestimation of the rate and the increase of the non-governmental credit. Moreover, the current account deficit is significantly improved after the crisis.

The general capacity of the model is relatively good if we consider the values obtained with the panel data (pseudo R2 amounts at 0.2513). However, this is not the only evaluation criterion. Table 4 offers a more detailed analysis of the performance degree for the model calculated and in relation to the probability threshold chosen for signalling the crises.

Model performance degree (with crisis threshold of 10%):

Table 4

	Signal		
Crisis	S=0	S=1	TOTAL
y=0	1825	148	1973
y=1	58	89	147
TOTAL	1883	237	2389

% correctly estimated observations: 90,28%

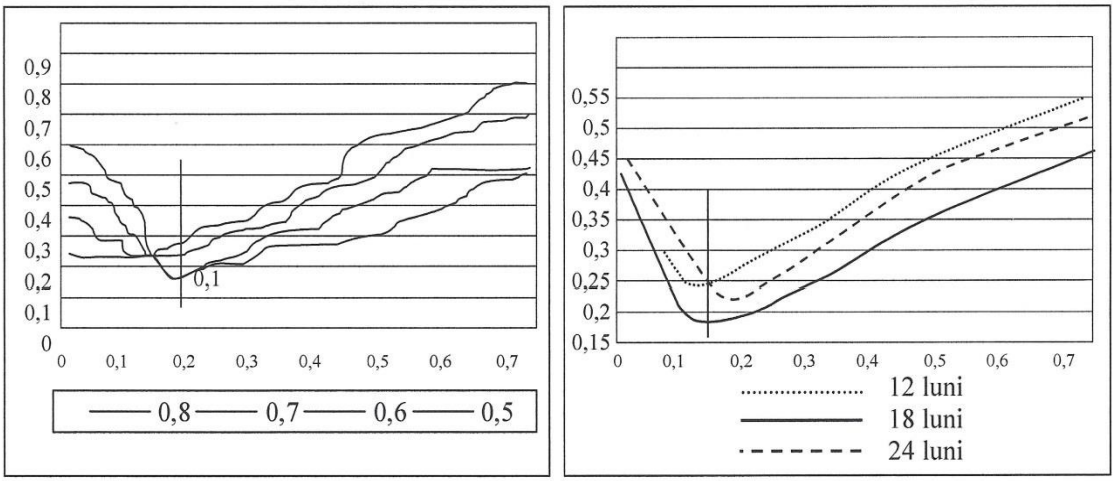
% correctly estimated crises: 60,54%

% false alarms in relation to the total number of alarms: 62,45%

% signal crisis probability: 37,55%

% non-signalled crisis probability: 6,15%

The choice of this threshold was made by minimizing a function of cost which was presented for the limited dependent variable-logit multinomial method and which, in the event of an authority that is neutral to risk (0=0.5), amounts at 10 %, as one can see in Graphic 1. By increasing the risk degree, one has to consider the compromise (trade-off) between the costs of non-signalling a crisis and the one of signalling a crisis (i.e. implementing a measure) for the situations in which there are no real chances for a crisis to occur.



Graphic 1. The policy function in the event of risk neutrality for different crisis period and different degrees of risk aversion (%)

The performance degree of the model is estimated for the pre-crisis period (i.e. for PCY=1). In this case, 90% of the observations and 60.5 % of the crises are correctly estimated, while the crisis probability indicated by the signal amounts at only 37.55 %. In comparison with the models estimated by the International Monetary Fund (IMF-Developing Country Studies Division), Kaminsky-Lizondo-Reinhart (1998)[14], the GS-WATCH model of Goldman-Sachs and Credit Suisse First Boston[15], the estimated model is quite successful as to the number of correctly estimated observations, the total number of false alarms, the likely non-signalled crises, the signalled crisis probability (37.55 % in comparison with 37.2 %, 29.7 %, 26 % and respectively 6.5 %).

The percentage of correctly estimated crises remains relatively around the values obtained by these models (60.54 % in comparison with 65.1 %, 59.8 %, 62.2 %, respectively 61.1%). However, the performance of the model is below the models estimated by Bussiere and Fratzscher (2002)[16]: the number of crises that are

correctly estimated in their case is 73.7 %, the total number of false alarms is: 44.1 %, the signalled crisis probability is of: 55.9 %; the inclusion of countries that did not experience major crises might explain these results. Similarly, the performance of the model may be assessed in the graphical analysis of the estimated crisis probability established for each country and also by comparing the obtained results with the real data.

6. Simulating the crisis probability by using scenarios

As previously mentioned, the logit multinomial model consists in dividing the crisis period into two sub-periods: the pre- and post-crisis periods; this allows avoiding the postcrises bias effect, caused by the different evolution of indicators during the two sub-periods. Table 5 presents the medium values of the studied indicators. For example, the pre- crisis period is characterised by a high overestimation of the real effective exchange rate, while the post-crisis period incurs a devaluation of the real effective exchange rate. The normal periods are the ones in which the real effective rate does not record significant deviations from the trend.

Intermediate values for the used indicators Table 5

Variables	The whole period	The normal period	The pre-crisis period	The post-crisis period
Overestimation of the real exchange rate	1.04	0.45	13.77	-1.14
NGC/GDP *	5.02	4.87	7.69	6.39
CA/GDP *	-2.26	-2.50	-3.63	0.3
M2/Reserves	2.67	2.52	4.21	3.02
Export growth	12.01	14.06	4.97	0.16

*NGC = non-governmental credit; CA = Current account

Due to the impossibility to interpret the coefficients in a logit/probit regression as marginal effects, as a consequence of the non-normal distribution of the explained variable, the marginal effects must be calculated at a pre-established value for the explanatory variables.

Table 6 presents the effect of the estimated probability in relation to a set of scenarios. As a reference level, we chose the scenario in which all variables have a medium level during the normal period. In this scenario, the probability for a crisis to occur during the next 12 months is extremely low, i.e. 2.02 %. On the other hand, when all variables have a medium level during the crisis period, the probability for a crisis to occur is significantly higher in comparison with the normal period, amounting at 27.58 %.

The probability for a currency crisis to appear – scenarios Table 6

Scenarios	Crisis Probability (%)	Modification of the probability (expressed as percentage points)
(1) All variables amount at the intermediate level for a normal period	2.02	-
(2) All variables amount at an intermediate level for the crisis period	27.58	+25.56
(3) All variables amount at the intermediate level for the normal period, except for:		
(a) The exchange rate +2%	2.51	+0.49
(b) The exchange rate +5%	3.48	+1.46
(c) The exchange rate +10%	5.92	+3.90
(d) M2/reserves+2.5%	7.33	+5.21
(e) CA/GDP: deterioration with 5%	2.53	+0.51

(f) NGC/GDP: growth with 5%	2.16	+0.14
(g) Decrease of the export exchange rate with 15%	2.22	+0.2

The table points out that, in order to establish the impact of the different variables on the probabilities estimated by the crisis, one considers that all variables amount at an average level during a normal period, except for a variable which records a change as indicated in the table. One can notice that the highest impact is illustrated by the increase of the M2/reserves ratio, whose double value (illustrating the pre-crisis period) generates a modification in the crisis probability of 7.23 %, i.e. 5.21 percentage points in relation to the reference level and an overestimation of the real effective exchange rate of 10 %, which indicates a probability of almost 6 %, i.e. 3.9 percentage points higher than a normal period.

The presented analysis confirms the previous one, which is based on noise to signal ratio and in which M2/reserves and the increase in the real level of the currency exchange rate were the factors for which the ratio between the signalling of a false crisis related to periods that did not incur crises and the ratio between signalling a real crisis related to the period of crisis was the lowest one of all.

7. Conclusions

The present paper empirically tested two early warning systems for currency crisis on a sample of emerging countries. The approach, using the methodology proposed by Bussiere and Fratzscher (2002), more comprehensive in comparison with the one initiated by Kaminsky, Lizondo and Reinhart (1998), suggested the main indicators signalling currency crises: overestimation of the national currency (calculated as a deviation from the real effective rate in relation to a linear trend), the rhythm of increase of the non-governmental credit expressed as a percentage in relation to the GDP, the share of the current account deficit incurred by the GDP, M2/reserves and the rhythm of increase in exports.

Of the above mentioned indicators, M2/reserves and overestimation of the national currency have the most serious impact on triggering a potential crisis, caeterus parebus (although, in reality, defining factors may manifest simultaneously).

In terms of central banks' reserves, an example is the attack on the Thai baht which have been exerted in July 1996, following the collapse of the Bangkok Bank of Commerce and the Bank of Thailand's injection of liquidity to support the financial system. In May 1997 occurred the most severe attack on the baht. First of all, the capital markets started reporting increasing purchases of U.S. dollars by Thai banks, finance companies, and corporations, as well as accounts of capital flights. This was followed by more intensive speculative pressure on the baht, primarily on the parts of hedge funds and foreign banks. The Bank of Thailand drawing down its reserves and sold US$26 billion forward, based on an end June 1997 estimate. On 15 May, the Central Bank stopped intervening and started to let the interest rate rise, while instituting capital controls to defend the currency and on 2 July, the baht was finally allowed to float. This drove down the currency by 15% onshore and 20% offshore on the same day.

The performance degree of the logit multinomial model, in comparison with the models estimated by the International Monetary Fund (IMF-Developing Country Studies Division), Kaminsky-Lizondo-Reinhart (1998), GS-WATCH model of Goldman-Sach and Credit Suisse First Boston, is higher, but it is lower than the performance of the model developed by Bussiere and Fratzscher (2002); the inclusion of certain countries in the sample did not record significant crises, which may be regarded as a potential explanation of this fact.

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