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A MULTINOMIAL APPROACH TO EARLY WARNING SYSTEMS FOR DEBT CRISES

by Alessio Ciarlone * and Giorgio Trebeschi **

Abstract

This paper develops an early warning system for sovereign debt crises, broadly defined as episodes of outright default, failure of a country to be current on external obligations and substantial access to IMF resources. It estimates a multinomial logit model that makes it possible to differentiate between three regimes labelled 'tranquil', 'pre-crisis' and 'adjustment'. The model includes a large set of macroeconomic variables and is able to predict, in-sample, 78 per cent of onsets of crisis while sending false alarms in 34 per cent of tranquil cases; its out-of-sample performance is very similar, with 70 per cent of entries into crisis correctly predicted and 20 per cent of tranquil cases triggering false alarms.

JEL Classification numbers: H63, E66.

Keywords: emerging markets, early warning system, debt crises, default.

Contents

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1. Introduction

Emerging market economies have experienced disruptive crises caused by such factors as their poorly developed financial systems, volatile macroeconomic policies, weak banking systems, high dependence on external capital flows and uncertain growth prospects.

Accordingly, both the academic and the official sector have endeavoured to develop models which are able not only to identify weaknesses and vulnerabilities in emerging market economies, but also to send timely and correct signals about the onset of a financial crisis, the so-called early warning systems (EWS).

Most of the EWS models developed so far have tried to signal the onset of currency and banking crises, both individually or jointly determined (so-called twin-crises). The seminal papers in the field are those by Kaminsky, Lizondo and Reinhart (1998) and by Frankel and Rose (1996), while a thorough review of these models can be found in Berg, Borensztein and Pattillo (2004).

Until now, however, little work has been done on 'debt' crises, which can be broadly defined as episodes of default or failure to be current on external obligations. The period since 1994 has witnessed large sovereign and corporate defaults, as well as difficulties in servicing foreign-currency debt.

Currency and debt crises may be generated by common factors, such as unfavourable macroeconomic developments, deterioration in external financing conditions (e.g. a sudden reduction in capital flows or a sharp rise in their cost) or an increase in the extent of international investors' risk aversion. Nevertheless, currency and debt crises do remain quite distinct events, considering that:

1) The two types of crises are not perfectly correlated, as is shown in Sy Amadou (2003): a country may have a currency crisis unaccompanied by a debt crisis, or instead may fall into arrears or default on its external debt without any major disruption in the exchange rate, as happened in Pakistan in 1999. In a sample of 59 countries for the period from 1970 to 1999, Reinhart (2002) reaches similar conclusions: although in developing countries there is a strong link between currency crises and default, "… currency crises … do not, in about one-half of the cases (even in developing countries), necessarily lead to default …".

2) It is not clear what the causal relationship should be. In fact, one could expect a sharp depreciation of the exchange rate in response to an excessively high growth of the

external debt or a rapidly worsening scenario for the country's financing needs; under such a scenario, investors might doubt the government's ability to face its external obligations and therefore start selling off assets denominated in that particular currency.

The literature on the empirical determinants of a debt crisis is quite small compared with the large body of theoretical and empirical work on currency and banking crises. A broad classification is between models based on the evolution of a particular set of macroeconomic variables, that could lead to the build-up of a crisis, and models that extract information on the probability of a credit event from financial data and the market prices of widely traded financial instruments such as sovereign bonds or, more recently, credit default swaps (CDSs). As recognized by the IMF itself (2002), any macro-based model should be complemented with information on market expectations extracted from bond spreads as well as from CDSs. A detailed description of the above-mentioned categories of EWSs for debt crises can be found in Ciarlone and Trebeschi (2004).

The aim of this paper is to develop an EWS for sovereign debt crises, which are broadly defined as episodes of outright default, failure of a country to be current on external obligations and substantial access to IMF resources. The EWS is based on a multinomial logit which allows for three regimes, labelled 'tranquil', 'pre-crisis' and 'adjustment'. The model includes a large set of macroeconomic variables and is able to predict, in-sample, 78 per cent of onsets of crisis while sending false alarms in 34 per cent of tranquil cases; its out-of-sample performance is very similar, with 70 per cent of entries into crisis correctly predicted and 20 per cent of tranquil cases triggering false alarms.

The paper is organized as follows: section 2 covers the definition of debt crisis, the data set and the event study analysis; section 3 presents the econometric specification, i.e. the multinomial logit; section 4 concludes.

2. Definition of Debt Crisis, Data and Event Study Analysis

In defining a debt crisis, the problem is that the event may take on different forms, ranging from an outright default on part or all of the stock of external or public debt, to debt-servicing difficulties determined more by illiquidity than by insolvency. These increasing debt servicing difficulties might well be signalled by the accumulation of interest or principal arrears (see Detragiache and Spilimbergo, 2001) or by a worsening of the market

evaluation of a country's creditworthiness, as measured by an increasing spread over US bonds or euro-denominated securities (see Pescatori and Sy, 2003). The very recent past has also witnessed many instances of outright default being prevented by large aid packages provided by the International Financial Institutions (e.g. Turkey in 2001 and Brazil in 2002) or by restructuring agreements with the private sector (e.g. Uruguay in 2002).

In what follows, we will describe the procedure used to define the dependent variable, i.e. the occurrence of a debt crisis, the macroeconomic variables that we think may be significant in determining such an event and their behaviour before and after the occurrence of a crisis. All of this will serve as a necessary background for the econometric analysis developed in section 3.

2.1. A new definition of debt crisis

Our debt crisis indicator is derived from data provided by the World Bank's Global Development Finance database (GDF), the IMF's International Financial Statistics database (IFS), the Paris Club website and internal sources.

More precisely, we have defined a debt crisis as an event when at least one of the following conditions occurs:

1) A country has officially declared a *moratorium* on public or external debt payments, [1] or it has signed a debt restructuring or rescheduling agreement with official and/or commercial creditors. [2]

2) A country has missed payment of interest and/or principal on external obligations vis-a-vis official and commercial creditors in an amount of more than 5 per cent of the debt service ratio paid by year-end. [3]

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[1] Data on sovereign defaults are essentially drawn from the database the Bank of Italy uses to run the quarterly sovereign risk assessment for Italian banks.

[2] Information about official debt restructurings has been mainly drawn from the Paris Club web site (www.parisclub.org) and the World Bank's yearly publication Global Development Finance; this is the only source of information on commercial debt restructurings.

3) A country has accumulated arrears of interest and/or principal on external obligations towards official and commercial creditors in an amount of more than 5 per cent of the total external debt outstanding by year-end. [4]

4) A country has received large assistance from the IMF, where large is defined as access to more than 100 per cent of its relative quota. [5]

This definition includes the whole range of forms that a debt crisis can take: outright defaults, potential defaults avoided only thanks to a restructuring/rescheduling of external debt or to the interventions by the IFIs, mounting debt-servicing difficulties, possibly leading to a missed payment on the country's external obligations or the accumulation of interest and/or principal arrears.

Table 1 gives the chronology of crises from 1980 to 2002 for 28 emerging market economies with significant market access: [6] for each country in the sample, the table shows the number of episodes as well as their average length. For the sample as a whole, we found 44 debt crises with an average length of almost 7 years.

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[3] According to the Bank of Italy's methodology, missed payment is constructed, first by summing the "flow" of interest and/or principal arrears incurred by a country during the year and then by dividing this sum by the total debt service effectively paid by year-end.

[4] Arrears are constructed by first summing the stock of interest and/or principal arrears accumulated by a country in subsequent years and then by dividing this sum by the total external debt outstanding at year-end.

[5] The IMF's International Financial Statistics (IFS) database hosts information on the country's position in the Fund's capital (i.e. its quota), on the amount of financial resources agreed in each program (typically Stand By Agreement and Extended Fund Facility) and on the amount of financial resources effectively drawn by the country. In order to detect a crisis, we take the ratio between the amount effectively drawn and the country's quota in the Fund's capital.

[6] In order to construct our sample, we started with the set of 31 emerging market economies included in the JPMorgan EMBI Global Diversified. As a second step, four countries (Bulgaria, Cote d'Ivoire, Lebanon and Ukraine) that lacked comprehensive macroeconomic time series were dropped while South Korea was included. After this second step, the dataset comprised the following 28 countries: Argentina, Brazil, Chile, China, Colombia, Dominican Republic, Ecuador, Egypt, El Salvador, Hungary, Indonesia, Korea, Malaysia, Mexico, Morocco, Nigeria, Pakistan, Panama, Peru, Philippines, Poland, Russia, South Africa, Thailand, Tunisia, Turkey, Uruguay and Venezuela. We also tried to include countries such as the Czech Republic, Hong Kong, India and Singapore, but lack of comprehensive macroeconomic data forced us to leave them out.

Table 1

EMERGING MARKET ECONOMIES AND DEBT CRISIS EPISODES, 1980 – 2002

Country	Number of crises	Years in crisis	Average length	Crisis episodes
Argentina	2	15	7.5	1983 – 1995; 2001 - …
Brazil	2	16	8.0	1983 – 1993; 1998 - …
Chile	1	8	8.0	1983 – 1990
China	---	---	---	---
Colombia	1	1	1.0	1988
Dominican Rep.	2	19	9.5	1982 – 1999; 2002 - …
Ecuador	1	18	18.0	1983 – 2000
Egypt	2	13	6.5	1980 – 1991; 1995
El Salvador	2	5	2.5	1984; 1989 – 1992
Hungary	---	---	---	---
Indonesia	1	6	6.0	1997 - …
Korea	3	6	2.0	1980 – 1981; 1984; 1997 – 1999
Malaysia	---	---	---	---
Mexico	2	13	6.5	1982 – 1992; 1995 – 1996
Morocco	2	11	5.5	1983 – 1992; 1999
Nigeria	1	17	17.0	1986 - …
Pakistan	2	6	3.0	1981 – 1982; 1998 – 2001
Panama	1	13	13.0	1983 – 1995
Peru	3	16	5.3	1980; 1983 - 1996; 2000
Philippines	2	9	4.5	1984 – 1991; 1994
Poland	1	13	13.0	1981 – 1993
Russia *	1	14	14.0	1989 - …
South Africa	2	6	3.0	1985 – 1989; 1993
Thailand	2	4	2.0	1981; 1997 – 1999
Tunisia	1	1	1.0	1991
Turkey	2	6	3.0	1980 – 1982; 2000 - …
Uruguay	3	5	1.7	1983; 1986 - 1988; 2002 - …
Venezuela	2	12	6.0	1984 – 1994; 1998
Total	**44**		**6.7**	

Sources: authors' calculations based on IMF and World Bank data.
* Data prior to 1992 are for the former Soviet Union.

For every country in the sample, Table 2 shows which, among the different factors mentioned above, are considered the main determinants of a crisis period.

Table 2

EMERGING MARKET ECONOMIES AND DEBT CRISES' DETERMINANTS

	Entry into crisis	Moratoria and debt restructurings	IMF position	Missed payments	Arrears
Argentina	1983	✓		✓	✓
	2001		✓		
Brazil	1983	✓			
	1998		✓		
Chile	1983	✓			
Colombia	1988			✓	
Dominican Republic	1982			✓	
	2002			✓	
Ecuador	1983	✓			
Egypt	1980			✓	
	1995			✓	
El Salvador	1984			✓	
	1989			✓	
Indonesia	1997		✓		
Korea	1980		✓		
	1984		✓		
	1997		✓		
Mexico	1982			✓	
	1995		✓		
Morocco	1983	✓			
	1999			✓	
Nigeria	1986	✓		✓	
Pakistan	1981	✓			
	1998			✓	
Panama	1983	✓			
Peru	1980	✓			
	1983	✓	✓	✓	
	2000	✓			
Philippines	1984	✓		✓	
	1994	✓			
Poland	1981	✓			✓
Russia	1989			✓	
South Africa	1985	✓			
	1993	✓			
Thailand	1981		✓		
	1997		✓		
Tunisia	1991		✓		
Turkey	1980	✓			
	2000		✓		
Uruguay	1983	✓			
	1986	✓			
	2002		✓		
Venezuela	1984			✓	
	1998	✓			

2.2. Variables used in the econometric specification

Our set of independent variables comprises 28 macroeconomic and financial indicators, largely drawn from the literature on debt sustainability: essentially, they measure the burden of external indebtedness, the resources allocated to servicing it, the country's ability to generate foreign-currency revenues, the external monetary and financial conditions, the net capital flows. Table 3, constructed following the suggestions in Manasse et al. (2003), gives the mean of each variable in the entire sample, for non-crisis episodes, for the year before the onset of a debt crisis, for in-crisis years and for years before a country exits a crisis. [7]

As the table shows, all the variables that measure external debt (expressed as a percentage either of GDP or of exports) and the flow of resources allocated to its service (divided either by exports or by international reserves) clearly worsen in the years leading up to a crisis. Those variables are below sample average in non-crisis years, they increase in the year preceding a crisis, and most of them continue to rise during the crisis itself, dropping to significantly lower levels when a country exits from the negative event.

The variables that measure the country's ability to generate foreign-currency revenues show the opposite pattern, i.e. they significantly decrease in the years preceding a crisis: this is the case of export growth, as well as more general openness to international trade; moreover, debt crises are also determined by a sharp reduction in the growth rates of private capital flows.

All the measures of the level of international reserves (scaled to GDP, short-term debt, total external debt) show a sharp reduction in the years leading up to a debt crisis, while the ratios of short-term debt (scaled to GDP, international reserves and total external debt) significantly increase from their levels in tranquil periods.

[7] A complete description of all the macroeconomic variables used in the econometric analysis is given in Appendix 1.

Table 3

DESCRIPTIVE STATISTICS OF MACROECONOMIC AND FINANCIAL VARIABLES

Variable name	Sample mean	Non crisis	Before crisis	Crisis	Before exiting crisis
Central government budget balance / GDP	-3.3	-2.9	-3.3	-3.9	-2.9
Current account balance / GDP	-1.9	-2.0	-3.7	-1.9	-1.2
Current account balance / Short-term debt (*)	-16.7	-18.2	-33.3	-12.3	-19.2
Export growth rate	7.4	9.4	1.9	5.2	8.9
Federal funds rate	7.1	7.4	8.5	7.1	6.9
Import growth rate	7.5	9.9	-0.4	5.7	9.3
Inflation rate (end of period)	72.8	21.2	20.6	173.1	73.6
Interest on external debt / International reserves	75.9	47.9	142.5	117.0	57.8
International reserves / GDP	8.7	10.0	6.5	6.2	9.3
International reserves / Imports (in months of cover)	5.1	5.1	4.7	4.6	5.9
International reserves / Short-term debt (*)	101.8	125.5	73.6	58.0	127.5
International reserves / Total external debt	21.5	29.0	14.0	9.6	18.3
International reserves growth rate	18.4	14.3	0.9	28.7	25.3
Net inward direct investment / GDP	1.4	1.6	1.0	1.2	1.5
Openness to international trade	43.9	47.9	36.9	37.8	40.9
Private capital flows growth rate	98.8	74.7	24.0	66.9	535.1
Private capital flows / GDP	2.7	3.1	3.6	2.6	1.7
Real effective exchange rate	101.4	110.4	117.2	87.7	87.6
Real GDP growth rate	3.4	4.4	2.4	2.2	3.1
Short-term debt (*)/ GDP	13.0	11.4	13.4	15.5	10.7
Short-term debt (*)/ International reserves	275.5	196.7	410.1	411.1	174.9
Short-term debt (*)/ Total external debt	24.8	26.7	28.5	21.7	21.0
Terms of trade	107.5	106.9	113.3	109.8	97.7
Total debt service / Exports	44.7	37.2	54.9	54.9	46.1
Total debt service / International reserves	173.2	120.5	357.5	244.1	116.2
Total external debt / Exports	318.0	232.9	336.8	454.1	333.9
Total external debt / GDP	50.6	41.1	47.0	65.9	51.0
Trade balance / GDP	-1.4	-1.9	-3.4	-0.1	-2.3

Sources: IMF, *World Economic Outlook*, Sept. 2004; World Bank, *Global Development Finance*, 2004; Economist Intelligent Unit; authors' calculations

(*) Short term debt is measured on a remaining maturity basis.

2.3. Event study analysis

Event study analysis complements the simple descriptive statistics and is a useful tool to investigate the behaviour of explanatory variables around default episodes and to give a

graphical interpretation of it. The results of the event study analysis are shown in Chart 1: the bold horizontal line represents the average value of the variable during tranquil periods, whereas the solid line shows the average value of the variable during stress times with a 95 per cent confidence interval around it, identified by the two dotted lines. Time goes from *t-3* to *t+3*, where *t* is the year in which our debt crisis indicators is equal to one for the first time, thus signalling a crisis entry. The event study analysis suggests the following results:

– Measures of external debt service are significantly different during crisis periods with respect to tranquil times: interest payments on external debt, which average 54 per cent of the level of international reserves during non-crisis periods, more than double in the year preceding a credit event and become increasingly larger in the crisis year and in the following one; total debt service, which includes principal repayments as well, displays a similar pattern, regardless of whether it is expressed as a percentage of international reserves or of exports; total external debt to GDP increases during the run-up to a crisis and, at *t+1*, it becomes significantly higher than its average in tranquil periods.

– Real GDP growth rates are not only significantly lower during pre-crisis years than the tranquil periods' average, but they exhibit a further worsening during a crisis period, shifting from an average of 4 per cent to nearly 0.

– Measures of the level of international reserves change significantly during crisis periods: in particular, the level of reserves as a percentage of total external debt drops from 25.2 per cent during tranquil times to 14.4 in the year preceding a crisis.

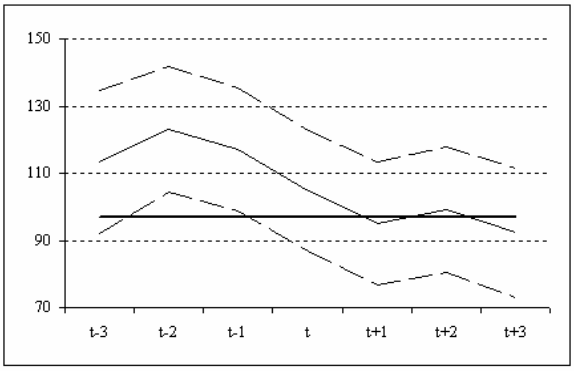
– Measures of external debt show revealing patterns: total external debt as a ratio to GDP increases from about 45 per cent in the years before a crisis to 60 per cent in the year after the credit event. Short-term debt over international reserves increases sharply in the run-up to a crisis, from about 220 per cent to 383 per cent. Short-term debt over total external debt is significantly higher than its average level during tranquil periods in all the years preceding the onset of a debt crisis.

– Federal funds rates are significantly higher, in the years before a crisis erupts, than the average for tranquil periods: this suggests that the higher the interest rate in the US, the harder it is for an emerging country to close its financing gaps.

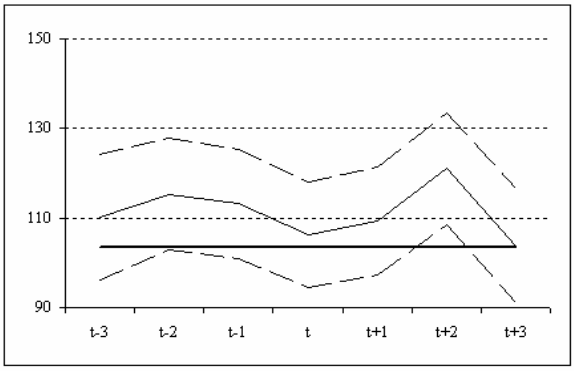
Among other variables, we found that private capital flows are not statistically different, in crisis years, from the average in tranquil periods (at least at a 95 per cent confidence level) but they show a steady declining pattern. This suggests that international investors provide financing to emerging market countries up to the year before a credit event occurs, withdrawing their funds thereafter.

Chart 1

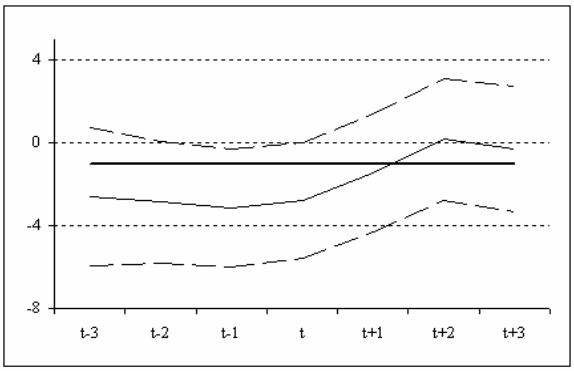
Real Effective Exchange Rate



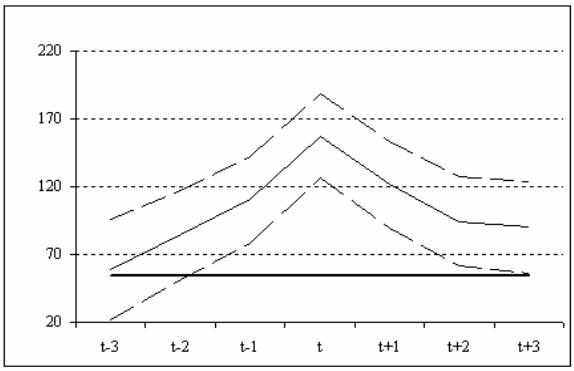
Terms of Trade



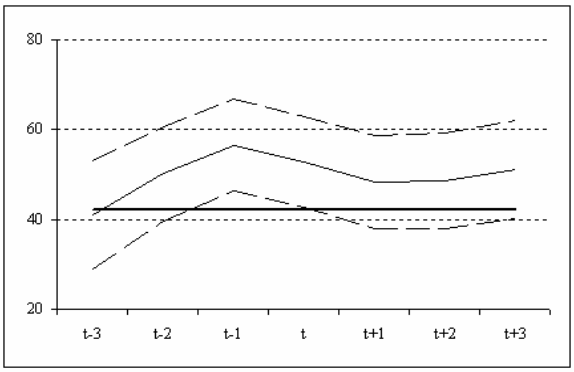
Trade Balance on GDP



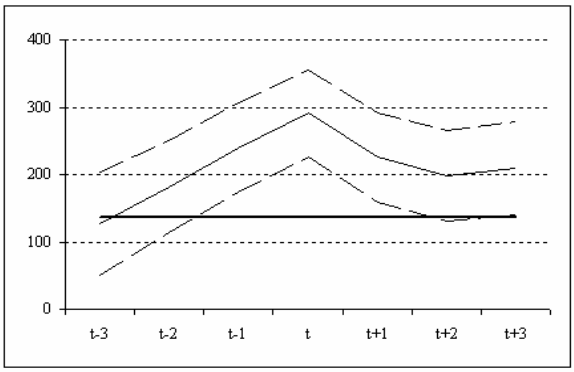
Interest on External Debt on International Reserves



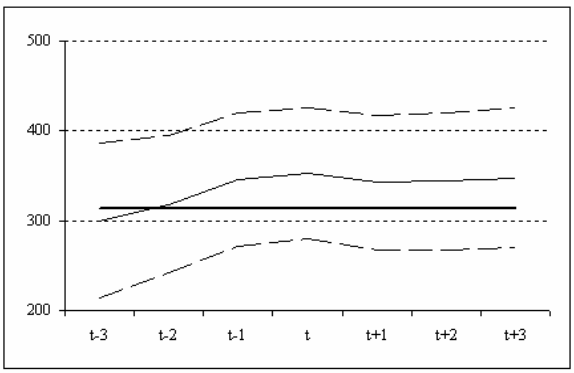
Total Debt Service on Exports



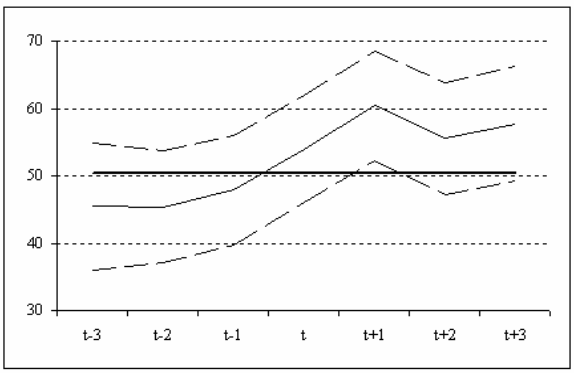
Total Debt Service on International Reserves



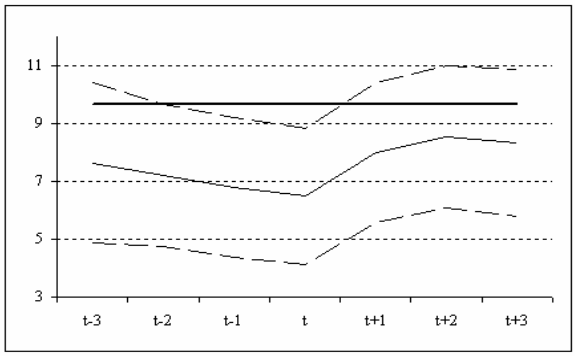
Total External Debt on Exports



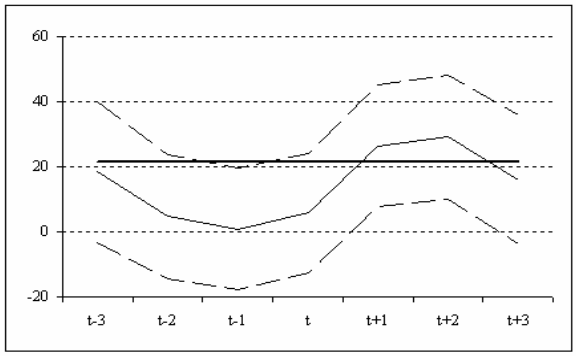
Total External Debt on GDP



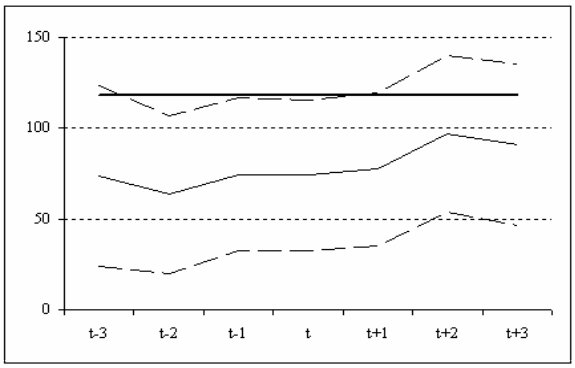
International Reserves on GDP



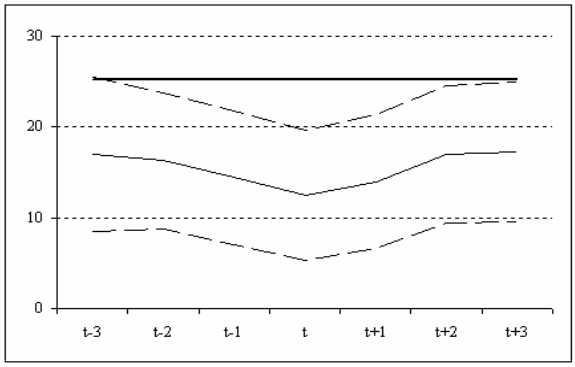
International Reserves Growth



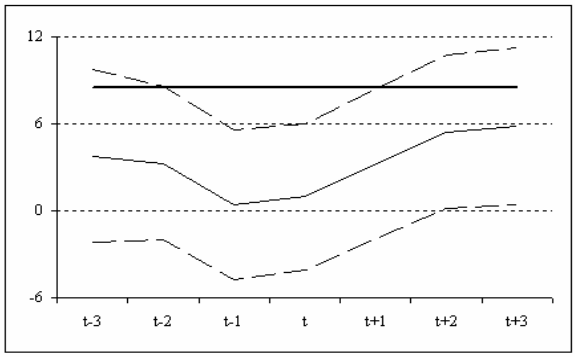
International Reserves on Short-Term Debt (residual maturity basis)



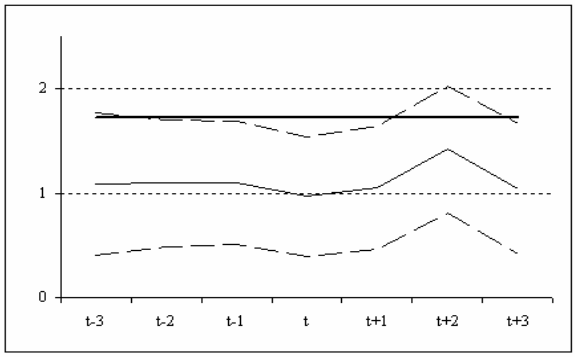
International Reserves on Total External Debt



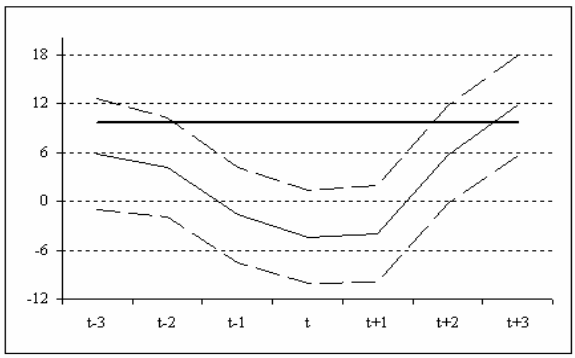
Export Growth



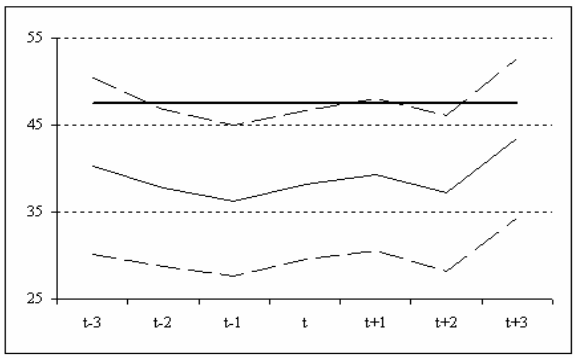
Net Inward Direct Investment on GDP



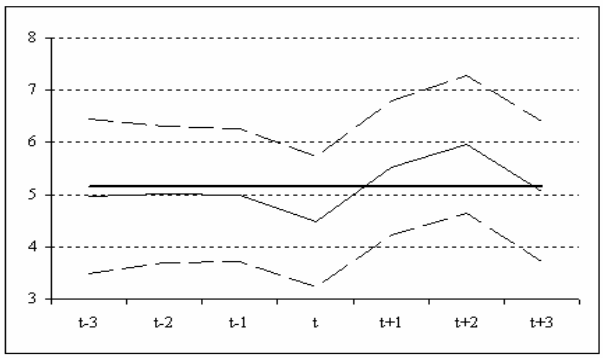
Import Growth



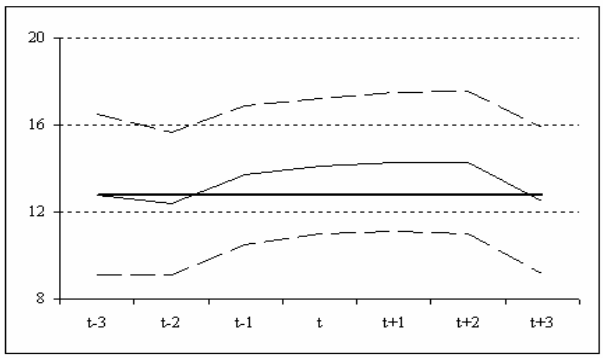
Openness to International Trade



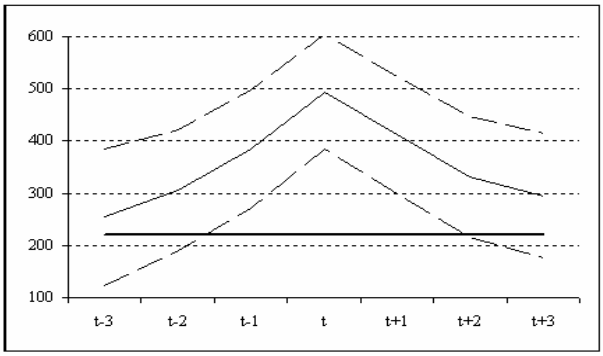
International Reserves on Imports
(in month of cover)



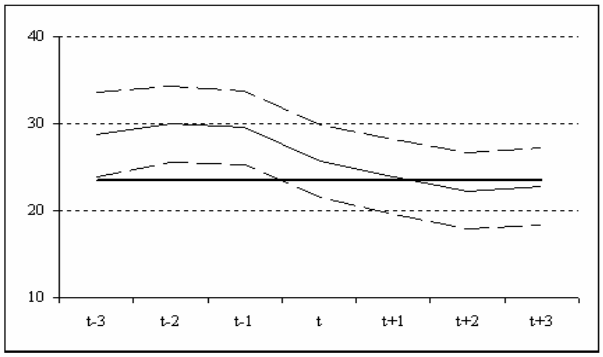
Short-Term Debt on GDP
(residual maturity basis)



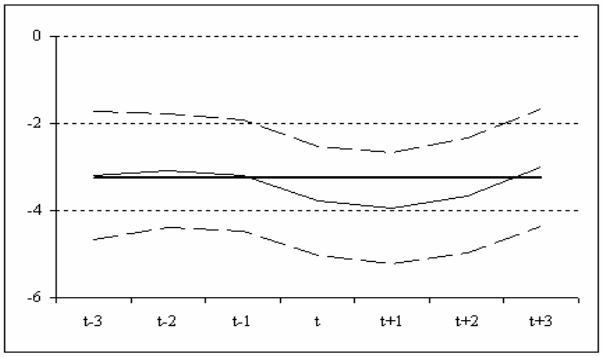
Short-Term Debt on International Reserves
(residual maturity basis)



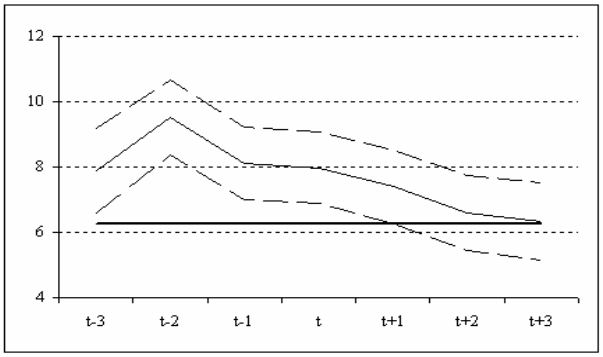
Short-Term Debt on Total External Debt
(residual maturity basis)



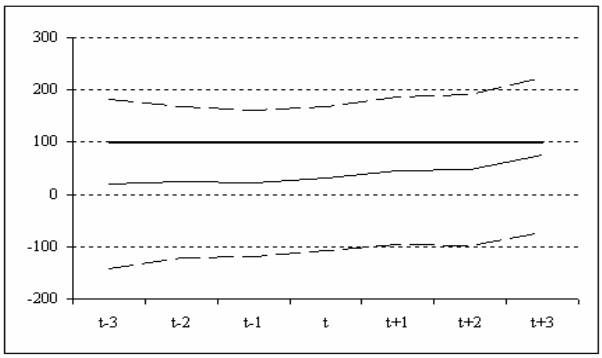
Central Government Budget Balance on GDP



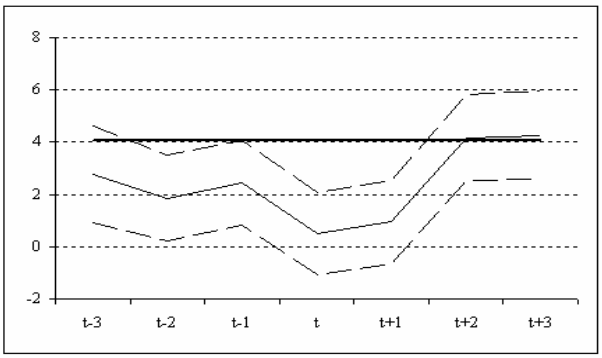
Federal Funds

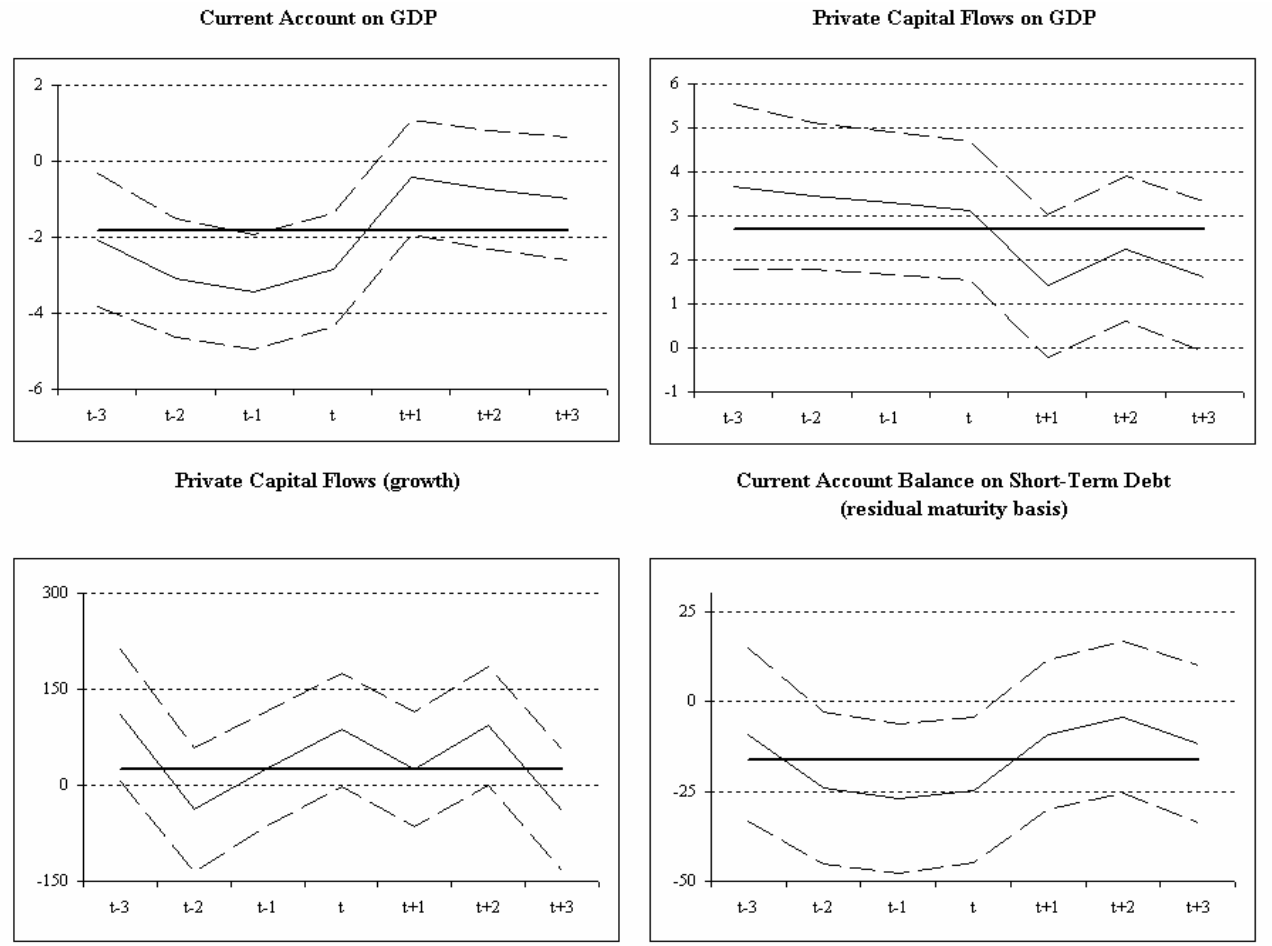


Inflation Rate (end of period)



Real GDP Growth Rate





3. A Multinomial Logit Early Warning System for Debt Crises

3.1. Econometric specification and estimation results

To find out which variables are significant in determining the onset of a debt crisis, we performed an econometric specification originally suggested by the work of Bussiere and Fratzscher (2002). More precisely, we have constructed a multinomial logit with three regimes: a tranquil period, during which macroeconomic and financial variables are on a sustainable path; a pre-crisis event, during which the levels assumed by a subset of macroeconomic and financial variables lead the country to experience a debt crisis in the following years; an adjustment phase, when the level of the macroeconomic variables revert

to a more sustainable path. The main difference with Bussiere and Fratzcher's seminal paper, besides the frequency of observations (monthly vs. annual), is that their model applies to currency, rather then debt, crises.

The multinomial logit approach has a great advantage over the simple binomial logit used, for instance, by Manasse et al. (2003), in that it makes it possible to construct more than two regimes and, thus, to model explicitly the 'crisis entry' as opposed to the 'adjustment' regime. In fact, it has been shown that the multinomial logit produces better econometric results, since it tackles the so-called post-crisis bias. This can be traced back to the difference between the behaviour of macroeconomic variables in the run-up to a crisis and the behaviour during the post-crisis adjustment period. Disregarding this different behaviour of independent variables, as may occur in a simple binomial logit model, can lead to biased coefficient estimates.

Taking into account this suggestion, we tried to apply the multinomial logit approach to the task of predicting debt crises. More precisely, the objective is to predict debt crises one or two years before they actually occur. For this reason, we have defined the three different regimes according to the rule shown in Table 4.

Table 4

REGIME DEFINITION IN THE MULTINOMIAL LOGIT MODEL

Definition of crisis as in section 2.1			**Regime in the multinomial**
At time t	**At time t+1**	**At time t+2**	**Model at time t**
0	0	0	Tranquil (Y = 0)
1	0	0	
0	**0**	**1**	**Pre – crisis (Y = 1)**
0	**1**	**0**	
0	**1**	**1**	
1	1	0	Adjustment (Y = 2)
1	1	1	
1	0	1 *	

* All the zeroes between two ones have been turned into ones and regarded as part of the adjustment process.

The selection of a two-year horizon in the definition of the dependent variable is related to the need of using the EWS as a regular tool for policy analysis. Publication lags of macroeconomic data reduce the nominal forecast horizon in practical applications, while implementation of pre-emptive policy measures would require a long time-span between the signal and the credit event. Using yearly frequency would linearly decrease the effective forecast horizon within the year to zero before the inclusion of a new observation, while the use of a two-year forecast horizon would help in part to mitigate this issue. Unfortunately, a longer forecast horizon implies a higher forecast variance.

Consistently with the binomial crisis indicator specified in section 2.1 - '0' for no crisis, '1' for crisis - at time *t* through time *t+2*, we have defined the multinomial regimes according to the following rule: a tranquil state is defined as the case in which the economy will not experience a crisis in the future (i.e. at times *t+1* and *t+2*) regardless of the current state (i.e. at time *t*), while a pre-crisis period is a situation in which an economy will face trouble in either or both of the following two years, provided that the crisis indicator is '0' at time *t*. All the other cases are treated as 'adjustment' periods after a crisis has already erupted and it is still unfolding.

The multinomial model is estimated with maximum likelihood, with the tranquil period as the benchmark, and using as regressors the set of 28 macroeconomic and financial variables that were the subject of the event study analysis. The entire sample runs from 1980 to 2002 but, considering a three-year estimation time period, we have been forced to disregard all the variables recorded both in 2001 and 2002. The final regression sample, therefore, contains 588 observations. Macroeconomic data at time *t* are use to predict crisis events at times *t+1* and *t+2*.

The probability of a country being in one of the three states is computed as follows:

$$\Pr\left(Y_{i,t}=0\right)=\frac{1}{1+\exp\left(X_{i,t}\cdot\beta_1\right)+\exp\left(X_{i,t}\cdot\beta_2\right)}$$

(3)

$$\Pr(Y_{i,t}=1)=\frac{\exp(X_{i,t}\cdot\beta_1)}{1+\exp(X_{i,t}\cdot\beta_1)+\exp(X_{i,t}\cdot\beta_2)}$$

$$\Pr(Y_{i,t}=2)=\frac{\exp(X_{i,t}\cdot\beta_2)}{1+\exp(X_{i,t}\cdot\beta_1)+\exp(X_{i,t}\cdot\beta_2)}$$

where Y=0, 1, 2 identifies, respectively, the tranquil regime (the benchmark state), crisis entry and the adjustment regime. Therefore, the vectors of coefficients β_1 and β_2 give a measure of the marginal effect of a change in the explanatory variables on the probability of being in state 1 or 2 relative to the probability of being in the tranquil regime, as shown in Equation (4):

(4)

$$\frac{\Pr(Y_{i,t}=1)}{\Pr(Y_{i,t}=0)}=\exp(X_{i,t}\cdot\beta_1)$$

$$\frac{\Pr(Y_{i,t}=2)}{\Pr(Y_{i,t}=0)}=\exp(X_{i,t}\cdot\beta_2)$$

Our estimation approach envisages three different steps:

– First, we run multinomial logit regressions for each of the 28 variables independently from one another, excluding all the variables that turn out to be insignificant in determining the probability of 'entering' and the 'being' in an adjustment phase, as well as the variables that, although significant, have a counterintuitive sign. This may raise some issues concerning omitted variables which, on their turn, may render coefficient estimates biased and inefficient, leading to the exclusion of variables that should be otherwise retained (Visco, 1978): we are aware of this drawback, which we address it in the third step.

– Second, we run so-called group-wise regressions, i.e. we group in families - essentially according to their nature - all the variables that got through the first step and then we run new multinomial logit regressions for each of these groups. As in the first phase, we retained only those variables that turned out to be significant and had the correct sign.

– Finally, we put together all the variables that got through the first and the second steps into a general multinomial logit regression. We restore variables that, for example, were found to be significant in the literature or displayed a particular behaviour in the event study analysis, but were dropped in either the first or the second steps. [8] Using a 'general-to-specific' approach in order to achieve a parsimonious model, we again drop all the insignificant variables.

At the end of this procedure, we retain just eight variables: the ratio of total external debt to exports; the federal funds rate; the interest payments on external debt scaled to international reserves; the real GDP annual growth rate; the ratio of short-term debt (calculated on a residual maturity basis) to total external debt; the total private capital flows on GDP; the annual inflation rate; the ratio of international reserves to total external debt.

Table 5 summarizes the results obtained from the estimation of the multinomial model. The first part of the table is the most important as it shows estimates for β_1, giving information about the likelihood of the economy's entering a crisis within two year as opposed to the likelihood of its remaining in a tranquil state. The second part of the table refers to estimates for β_2: these coefficients give information about the likelihood of a country's continuing to be in a recovery state as opposed to the likelihood of its returning to a tranquil state, where macroeconomic variables are on a sustainable path.

[8] This is essentially done in order to avoid the so-called omitted-variable bias, which arises when a significant explanatory variable is not taken into account in the regression, determining a significant correlation between the other regressors and the residual term. The omitted-variable bias is still more worrisome in non-linear estimation, such as the one we are performing here, since unlike ordinary least squares it is present whether or not the omitted regressors are correlated with the included ones. Two problems may arise in connection with the omitted variable bias. On the one hand, variables that are not part of the true model may be retained because the bias, induced by some omitted variable, makes them look significantly different from zero. This problem should be mitigated by the fact that the model is estimated in the first step using a large set of regressors that, hopefully, includes most of the true variables. On the other hand, the bias may cause the rejection of a variable that is part of the data generating process. This problem is addressed by adding variables that dropped out during the specification process but nonetheless may be important.

Table 5

MULTINOMIAL LOGIT ESTIMATION

Variable	**Coefficient**	**Std. Error**	**Z-Statistics**	**P-value**
Pre – crisis period (Y=1)				
CONST.	-4.39661	0.59114	-7.43748	0.00000
TEDGDP	0.01881	0.00831	2.26357	0.02360
FEDFUNDS	0.11367	0.03444	3.30027	0.00100
INTDEBTRES	0.00892	0.00235	3.78796	0.00020
REALGDP	-0.06079	0.02865	-2.12191	0.03380
STDRMBTED	0.02280	0.01057	2.15632	0.03110
TOTCAPFLOWS	0.06897	0.01887	3.65588	0.00030
CONST.	-2.77961	0.49251	-5.64375	0.0000
TEDGDP	0.05095	0.00670	7.60419	0.0000
INFL	0.00215	0.00044	4.92801	0.0000
RESTED	-0.07210	0.01834	-3.93212	0.0001
INTDEBTRES	0.00790	0.00249	3.17298	0.0015
Pseudo R-squared	0.27664			

According to the results of our estimation procedure reported in Table 5, we can conclude that:

- The amount of interests a country has to pay on its external debt obligations, scaled to international reserves, has a positive marginal effect on the probability of entering and being in a crisis: the higher the interest payments, or the lower the level of international reserves, the higher the probability of outbreak of a debt crisis - in the form of a missed payment or the accumulation of arrears - or the more difficult it is to exit from an ongoing crisis.

- The higher the burden of external indebtedness, measured as the ratio of total external debt to GDP, the higher the probability of outbreak of a debt crisis and the more difficult it is to exit from an ongoing one.

- The real GDP growth rate seems to have a positive marginal effect on the probability of entering a crisis: countries with higher growth rates are considered more creditworthy than others, making international investors more willing to lend.

- The federal funds rates have a positive marginal effect on the probability of entering a debt crisis: higher funds rate determines tighter liquidity conditions in international capital markets, leading to capital rationing or higher borrowing rates.[9]

- The higher the ratio of short-term debt to total external debt, the higher the probability of incurring a debt crisis.

- Total private capital flows as a ratio to GDP have a positive marginal effect on the probability of entering into a debt crisis. This may be related to the observation that international investors seem to provide financing to emerging market countries up to the onset of a credit event.

- Inflation rates seem to have a positive marginal effect on the probability of being in an adjustment phase. This might be due to inverse causality, i.e. episodes of hyperinflation generated by a debt crises coupled with a currency crisis. Such a situation can make an economy more fragile and a crisis more persistent. Moreover, the restrictive monetary policy needed to fight high inflation could increase the burden of a country's indebtedness, especially in those cases where a large portion of debt is linked to inflation.

- Countries with high levels of international reserves, scaled to total external indebtedness, are better placed to overcome negative credit events.

[9] There is a strand of empirical literature (reviewed in Mc Guire, P. and Schrijvers, M.A., 2003) that argues, in fact, that US monetary policy has a direct effect on the yield differentials between developed and developing bonds of the same characteristics. A restrictive monetary policy stance on the part of the FED goes along with wider spreads on emerging market sovereign debt.

3.2. Predictive ability

A first important test to evaluate the predictive ability of the model is to look at its in-sample predictive ability: a particular cut-off level, or threshold, has to be identified, above which the predicted probability could be considered as sending a signal that a crisis is about to occur. The question now is how this 'optimal' threshold should be calculated: the lower the threshold, the more signals the model will send, with the risk of many false alarms for crises that would never occur; the higher the threshold, the lower the numbers of signals, with the risk of not capturing the onset of a crisis that actually does occur in the forecast horizon. The former can be called 'type 1' errors, the latter 'type 2' errors, if the null hypothesis is no crisis. The choice of the 'optimal' threshold for the predicted probabilities will have to mediate between these two types of error, and will depend on which is considered more worrisome by the analyst. Since a precise rule to determine the 'optimal' cut-off level does not exist, this problem has been resolved by classifying an observation as predicting a crisis when the estimated probability exceeds the in-sample frequency of a crisis, i.e. when the economy goes from a tranquil state (Y=0 in the multinomial regime definition in Table 4) to a crisis (Y=1 in Table 4). Analogously, a threshold based on in-sample frequency has been established to determine the exit from a crisis, i.e. when the economy goes from a crisis state (Y=1 in Table 4) to a tranquil time (Y=0 in Table 4) instead of remaining in crisis (Y=2 in Table 4). [10]

[10] The threshold used for signaling entry into crisis is 12 per cent, while that for signaling being in a crisis is 32 per cent: these levels have been calculated as the in-sample frequencies of crisis entries and adjustment (for a definition of the regimes, please see Table 4).

Table 6

MULTINOMIAL LOGIT MODEL: IN-SAMPLE PERFORMANCE

True state	Correctly called	Not correctly signalled	**Total**
Pre – crisis	31	9	**40**
Adjustment	158	45	**203**
Tranquil	206	104	**310**
Total	**395**	**158**	**553**

Number of observations correctly called	71%
Number of crisis correctly called (2 years in adv.)	73%
Overall number of crisis correctly called	78%
Number of false alarms	34%

Crisis entries correctly called (31):		**Crisis entries not called (9)**
Argentina 1983, 2001	Pakistan 1998	Colombia 1988
Brazil 1983, 1998	Panama 1983	Dominican Rep. 2002
Chile 1983	Peru 1983, 2000	Egypt 1995
Dominican Rep. 1982	Philippines 1984	El Salvador 1989
Ecuador 1983	Poland 1982	Morocco 1999
El Salvador 1984	South Africa 1985, 1993	Pakistan 1982
Indonesia 1997	Thailand 1982, 1997	Philippines 1994
Korea 1984,1997	Turkey 2000	Russia 1989
Mexico 1982, 1995	Uruguay 1983, 1986, 2002	Tunisia 1991
Morocco 1983	Venezuela 1984, 1998	
Nigeria 1986		

The in-sample predictive ability of the model shows that the number of observations correctly called is 71 per cent and that the number of crises entries correctly picked up two years before the onset of the negative event is 73 per cent. Two more crises (Venezuela in 1998 and Turkey in 2000) are signalled just one year in advance, bringing the total of crisis entries correctly called to 78 per cent.

The model fails to predict the exact timing of the crisis that broke out in Russia in 1989 and lasted for the rest of the sample period (see Table 1): the crisis entry is in fact postponed to 1991 but, most importantly, when the crisis deepened in 1998 - with the default on ruble-denominated government bonds - the model correctly signals a high probability of a credit event.

The number of false alarms, i.e. the number of tranquil periods that are wrongly signalled as crisis, is about 34 per cent: in 104 cases out of 310 our model predicts a turbulent period, when a tranquil period materialises instead thereafter.

The predictive ability of the multinomial logit results has to be probed also, and especially, out-of-sample: we have re-estimated the model with macroeconomic data from 1980 to 1998 and predicted crisis events from 1999 onwards. The multinomial logit seems to perform well: the results for the out-of-sample predictive ability are shown in Table 7.

Table 7

MULTINOMIAL LOGIT MODEL: OUT OF SAMPLE PERFORMANCE *

True state	Correctly called	Not correctly signalled	**Total**
Pre – crisis	4	2	**6**
Adjustment	12	16	**28**
Tranquil	57	14	**71**
Total	**73**	**32**	**105**

Number of observations correctly called	70%
Number of crisis correctly called (2 years in adv.)	50%
Overall number of crisis correctly called	67%
Number of false alarms	20%

* The model is estimated with data up to 1998 to predict entries from 1999 onwards

Going back to 1998, we would have been able to anticipate 4 out of 6 crisis episodes, namely Peru and Turkey in 2000, Argentina in 2001 and Uruguay in 2002, but we would have missed the 1999 crisis in Morocco and the 2002 crisis in the Dominican Republic. The results show another desirable feature of our model: the number of false alarms is reasonably low, with 14 out of 71 tranquil periods incorrectly signalled as crisis events.

3.3. Robustness Analysis

Results from the multinomial logit estimation were tested for robustness along two lines

First, we reconsidered the definition of debt crisis. The original one encompasses four different conditions: a) outright default and debt restructurings with substantial haircut, b) significant access to IMF resources, c) excessive missed payments, d) excessive arrears on total external debt. To test for robustness, we performed two regressions using different

combinations of the four conditions. In the first one, the dependent variable was derived from conditions a) and b) only; in the second one, we also added in condition c).

Regarding the second line of action, we modified the thresholds used to identify a credit event. In the baseline scenario, a crisis occurs when one of the following conditions apply: a country has access to the IMF resources in excess of 100 per cent of its quota; the amount of missed payments is above 5 per cent of total debt service; the amount of arrears is above 5 per cent of total external debt. We modified the thresholds according to two scenarios: in the first, the critical level for missed payments and arrears was increased to 10 per cent; in the second, these levels were raised to 15 per cent, while the threshold for access to IMF resources was raised to 200 per cent of the quota.

As a final step, we re-estimated the model on a sub-sample of countries. In particular, we dropped China, because of the relatively low reliability of its data, and Hungary, Poland and Russia, considering that their past political regimes could have influenced their macroeconomic data.

The results of all the regressions previously outlined, not reported here for the sake of brevity, show that the original estimates are robust to such modifications. [11]

4. Conclusions

The paper focuses on debt crises episodes, whose importance has grown in the very recent past replacing currency crises as the major source of concern in emerging countries. The recent crises in Brazil, Uruguay and Turkey, with their potentially disruptive consequences on the stability of the entire global financial system, have led academics and private sector analysts to focus their attention on early warning systems that can detect the onset of such crises in a timely manner.

[11] The results of robustness analysis are available from the authors upon request.

Debt crises can take a variety of forms, ranging from outright default on part or all of the stock of external and/or public debt, to more general debt-servicing difficulties determined more by illiquidity than by insolvency. This consideration led us to construct a new debt crisis indicator able to take these different forms of crises into account. We used the indicator to evaluate a series of debt crisis episodes in the period 1980-2002 involving a relatively large sample of emerging countries with significant access to international capital markets.

The next step was to discover which factors, among a large set of macroeconomic and financial variables, were at the roots of a debt crisis. To perform this task, we ran a multinomial logit analysis which is characterised by three regimes instead of two, as in the classic logit models applied in debt crises literature until now. The variables found to be significant in explaining debt crisis episodes were mainly those that measure the burden of external indebtedness and its composition, the external financing conditions and other macroeconomic variables that measure the overall health of an economy, such as real GDP growth and inflation rates. The in-sample predictive power is good, with 78 per cent of crises episodes correctly called, and the model appears to be robust to different specifications regarding the dependent variable. Unfortunately, the model sends more than 30 per cent of false alarms. Finally, the out-of-sample predictive ability of our model turns out to be good as well, with a reasonably low level of false alarms, in the range of 20 per cent.

EWS models could be very useful instruments to guide policy analysis on emerging markets. To improve their information content and predictive power, ideal models should aim at integrating the approach based on macroeconomic data, outlined in this paper, with information extracted from market instruments (for example, sovereign bonds or, more recently, credit default swaps). In order to integrate these two aspects, timely information on the relevant macroeconomic variables is needed along with reliable and robust market data. With more frequent macroeconomic data and a larger set of countries for which financial data are available, further research could be carried out with the aim of better integrating the two aspects of an EWS for debt crises.

Appendix 1

Description of Regressors

VARIABLE	DESCRIPTION	SOURCE	NOTE
CENGOVBALGDP	Central government budget balance / GDP	IMF-WEO	Calculated as the ratio between series GCB (central government budget balance) and NGDP (gross domestic product, current prices, national currency). Missing data: Poland, 1980.
CAGDP	Current account balance / GDP	IMF-WEO	Calculated as the ratio between series BCA (current account balance) and NGDPD (gross domestic product, current prices, U.S. dollars).
CASTDRMB	Current account balance / short term debt (residual maturity basis)	IMF-WEO EIU	Calculated as the ratio between series BCA (current account balance) and D_SRM (short-term debt outstanding, remaining maturity basis). Data for Korea are drawn from the Economist Intelligence Unit database.
EXPGROWTH	Export growth	IMF-WEO	Calculated as the growth rate of the series BXG (exports of goods).
FEDFUNDS	Federal funds	Bloomberg	We have calculated it as a yearly average of daily observations.
IMPGROWTH	Import growth	IMF-WEO	Calculated as the growth rate of the series BMG (imports of goods).
INFL	Inflation rate (end of period)	IMF-IFS	Calculated as the annual variation of PCPIE (consumer prices, end of period)
INTDEBTRES	Interest on external debt / international reserves	IMF-WEO	Calculated as the ratio between series DSI (total debt interest paid) and BRASS (stock of reserves at year end).
RESGDP	International reserves / GDP	IMF-WEO	Calculated as the ratio between series BRASS (stock of reserves at year end) and NGDPD (gross domestic product, current prices, U.S. dollars). Missing data: Hungary, 1980-1982.

VARIABLE	DESCRIPTION	SOURCE	NOTE
RUIMP	International reserves / imports (in month cover)	IMF-WEO	Calculated as the ratio between series BRASS (stock of reserves at year end) and BMG (imports of goods). Expressed in month of cover of imports.
RESSTDRMB	International reserves / short-term debt (residual maturity basis)	IMF-WEO	Calculated as the ratio between series BRASS (stock of reserves at year end) and D_SRM (short-term debt outstanding, residual maturity basis). Missing data: Hungary, 1980-1982; Korea, 1980-1981.
RESTED	International reserves / total external debt	IMF-WEO	Calculated as the ratio between series BRASS (stock of reserves at year end) and D (total debt outstanding at year end).
RESGROWTH	International reserves growth	IMF-WEO	Calculated as the growth rate of the series BRASS (stock of reserves at year end).
FDIGDP	Net inward direct investments / GDP	IMF-WEO	Calculated as the ratio between series BFD (direct investment, net) and NGDPD (gross domestic product, current prices, U.S. dollars).
OPEN	Openness to international trade	IMF-WEO	Calculated as the sum of the series BXG (exports of goods) and BMG (imports of goods) divided by the series NGDPD (gross domestic product, current prices, U.S. dollars).
CAPFLOWSGROWTH	Private capital flows (growth)	IMF-WEO	Calculated as the growth rate of the series BFXP (private capital flows, net).
CAPFLOWSGDP	Private capital flows / GDP	IMF-WEO	Calculated as the ratio between series BFXP (private capital flows, net) and NGDPD (gross domestic product, current prices, U.S. dollars).
REER	Real effective exchange rate	IMF-WEO	We have used the series in levels. Missing data: Nigeria, 1980; Russia, 1980-1993; Tunisia, 1980-1982; Uruguay, 1980.
REALGDP	Real GDP (growth)	IIF	
STDRMBGDP	Short-term debt (on a residual maturity basis) / GDP	IMF-WEO	Calculated as the ratio between series D_SRM (short-term debt outstanding, residual maturity basis) and NGDPD (gross domestic product, current prices, U.S. dollar).

VARIABLE	DESCRIPTION	SOURCE	NOTE
STDRMBRES	Short-term debt (on a residual maturity basis) / international reserves	IMF-WEO	Calculated as the ratio between series D_SRM (short-term debt outstanding, residual maturity basis) and BRASS (stock of reserves at year end).
STDRMBTED	Short-term debt (on a residual maturity basis) / total external debt	IMF-WEO	Calculated as the ratio between series D_SRM (short-term debt outstanding, residual maturity basis) and D (total debt outstanding at year end).
TOT	Terms of trade	IMF-WEO	Series TTT (terms of trade, goods), in levels.
TDSEXP	Total debt service / exports	IMF-WEO	Calculated as the ratio between series DS (total debt service: interest and amortization paid) and BXG (export of goods).
TDSRES	Total debt service / international reserves	IMF-WEO	Calculated as the ratio between series DS (total debt service: interest and amortization paid) and BRASS (stock of reserves at year end).
TEDEXP	Total external debt / exports	IMF-WEO	Calculated as the ratio between series D (total debt outstanding at year end) and BXG (export of goods).
TEDGDP	Total external debt / GDP	IMF-WEO	Calculated as the ratio between series D (total debt outstanding at year end) and NGDPD (gross domestic product, current prices, U.S. dollars).
TRADEBALGDP	Trade balance / GDP	IMF-WEO	Calculated as the ratio between series BT (trade balance) and NGDPD (gross domestic product, current prices, U.S. dollars).

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