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In 2007 all ECB publications feature a motif taken from the €20 banknote.

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Abstract

Although many papers have already proposed empirical models of currency crises, the timing of such crises has received relatively little attention so far. Most papers use indeed a static specification and impose the same lag structure across all explanatory variables. This, by construction, prevents from specifically timing the crisis signals sent by the leading indicators. The objective here is to fill this gap by considering a set of dynamic discrete choice models. The first contribution is to identify how early in advance each explanatory variable sends a warning signal. Some indicators are found to signal a crisis in the very short run while others signal a crisis at more distant horizons. The second contribution is to show that state dependence matters, albeit mostly in the short run. The results have important implications for crisis prevention in terms of the timeliness and usefulness of the envisaged policy response.

JEL: C23, F15, F14.

Keywords: Dynamic discrete choice, panel data, currency crises, emerging markets, balance of payments, sudden stop, debt ratios.

Non-technical summary

The financial crises that swept emerging markets in the past decades have now been analyzed through a variety of empirical models. These models seek to statistically relate the occurrence of crises to lagged variables, which play the role of early warning indicators. Such indicators include, for instance, debt and liquidity ratios, current account and government deficits, indicators of private sector imbalances, contagion, and so forth. As financial crises are a relatively rare event, these models are usually estimated with a panel of emerging markets in order to have enough observations. In spite of important differences between each other (in terms of country coverage or specific econometric technique), most existing models share two noticeable characteristics. First, they are static models (the lagged dependent variable does not enter the equation) and second, they assume that all dependent variables enter the specification at the same lag. The aim of this paper is to test these two assumptions and to propose a framework within which they can be relaxed.

The first contribution of the present paper is to introduce a dynamic specification to model financial crises. Indeed, most existing models rely on a static specification, based on the assumption that the probability of a crisis in a given country is independent of whether this country has been hit by a crisis before. However, this assumption seems very unlikely, both in the short and in the long run (in technical words, there can be state dependence). Although the proposition that the occurrence of crises in the past can influence the likelihood to observe crises in the future may appear relatively intuitive, it has not been formally tested so far. In addition, the direction of the effect is not immediately clear. In the short run, the effect could indeed run both ways. On the one hand, if a crisis translates into a large proportion of liquid investment flowing out, it is unlikely that capital outflows happen again immediately afterwards (all the funds have been moved out); in this case, the lagged dependent variable would have a negative sign. On the other hand, a crisis may indicate that a country is more vulnerable than investors had initially thought, and induce those who have not done so yet to withdraw their investments, therefore increasing the risk of a future crisis; in this case, the lagged dependent variable would have a positive sign. In the long run, the effect could again work in both directions: a country that is accustomed to crises can be deemed inherently more vulnerable by investors while, by contrast, a country that has been hit by a crisis may benefit from higher vigilance by policy makers and investors, thus avoiding further crises. The question of state dependence has obvious policy implications: it would mean that, ceteris paribus, countries that have been hit by a crisis in the past may be, as a result, more (or less, depending on the sign) vulnerable.

However, the estimation of state dependence is complicated in the presence of idiosyncratic effects. The motivation for such effects comes from the fact that no model, no matter how rich, can take all country characteristics into account. Individual effects can then arise if there are some non-observable characteristics at stake. The present paper therefore investigates the role of country fixed effects using a conditional logit model. The two issues mentioned above (state dependence and individual effects) are closely related, as mentioned in particular by Heckman (1981a). This can be seen by considering the hypothetical case of two countries A, which is often affected by crises and B, which does not experience crises, the two countries being otherwise identical (they have similar fundamentals). In this example, it is hard to know whether the difference between A and B is due to (unobserved) idiosyncratic differences that make A inherently more vulnerable than B, or whether A's repeated crises are due to the fact that the first crises made A subsequently more vulnerable to future crises. This suggests that results on state dependence should be interpreted with caution.

The second contribution of this paper is to investigate the time horizon at which different indicators signal a crisis. Indeed, most existing models assume that the impact of all explanatory variables materialises at the same lag. This assumption can be questioned: for instance, one would expect that structural problems have an effect in the long run, whereas liquidity problems can materialise in the shorter run. This issue seems to have been overlooked by the existing literature, although it also has important policy implications. Often, policy actions taken at a given time can have an effect only in the medium to long run (e.g. reforms of the banking sector), whereas other types of action will yield an effect immediately (e.g. borrowing reserves).

To investigate the two issues above, the present paper uses a dynamic discrete choice (logit) model. Specifically, the dependent variable is a dummy variable equal to 1 if a country experiences a crisis and 0 otherwise, while the lagged dependent variable also appears on the right-hand side. The paper also discusses the common practice of using a forward index, indicating the presence of a crisis in a given time window. In addition, more lags of the explanatory variables are tested on the right-hand side than usually done in the literature. Results indicate that liquidity measures such as the short-term debt to reserves ratio and contagion both have a very short-run impact (four and six months, respectively), whereas a measure of banking sector fragility such as the so-called lending boom variable has a longer-run impact (about a year), and a measure of over-appreciation an even longer-run impact (two years). Finally, results also indicate that the lagged dependent variable enters the specification with a significant and positive sign, especially in the short run, which suggests that vigilance must not weaken after a first crisis has happened. In the conclusion, the paper also suggests possible extensions for future research.

1. Introduction

The currency crises that swept emerging markets in the past decades can be understood in various ways. By definition, they involve a large nominal and real depreciation of the domestic currency, but they are often also characterized by a "current account reversal", to use the terminology of Milesi-Ferretti and Razin (1996), as well as a "sudden stop" of international financial flows, to use the terminology of Calvo (1998)[1]. These phenomena actually represent different aspects of the same process: investors have lost confidence in the ability of a borrowing country to repay its debt, they refuse to roll over the debt and decide to withdraw their investment. This triggers a capital outflow (Calvo's "sudden stop"), a large depreciation and ultimately a large adjustment of the current account. In addition, crisis episodes also involve a change in domestic saving and investment.[2]

Currency crises have now been analyzed through a variety of empirical models, most of which consider a binary variable (equal to 1 if there is a crisis, 0 otherwise), which they try to explain using a set of relevant fundamentals.[3] The set of independent variables typically includes, among others, debt and liquidity ratios, current account and government deficits, indicators of private sector imbalances, contagion, and so forth. They can be transformed into "signals" when they cross a threshold (see Kaminsky and Reinhart, 1998a, b, 1999, 2000) or used as continuous indicators, in which case probit and logit models are a popular choice. As currency crises are a relatively rare event, these models are usually estimated with a panel of emerging markets.[4]

In spite of important differences between each other, most papers on the subject share two noticeable characteristics: first, they are static models (the lagged dependent variable does not enter the equation) and second, they assume that all dependent variables enter the specification at the same lag. Each of these two characteristics can be questioned. First, using a static model relies on the assumption that the probability of a crisis in a given country is independent of whether this country has been hit by a crisis before. However, this assumption seems very unlikely, both in the short- and in the long run; in other words, there can be state dependence, although the direction of the effect is not intuitively clear and needs to be formally tested. In the short run, the effect could indeed run both ways. On the one hand, if a crisis translates into a large proportion of liquid investment flowing out, it is unlikely that capital outflows happen again immediately afterwards (all the funds have been moved out). In this case, the lagged dependent variable would have a negative sign. On the other hand, a crisis may indicate that a country is more vulnerable than investors had initially thought, and induce those who have not done so yet

[1] See also Calvo, Guillermo, Izquierdo and Mejia (2004), and Calvo and Talvi (2005). The expression refers to the saying "it is not speed that kills, it is the sudden stop" and was previously used in this context by Dornbusch, Goldfajn and Valdes (1995).
[2] As noted in Gruber and Kamin (2005) for the Asian countries and in Calvo and Talvi (2005) for the Latin American countries, the adjustment mainly took place through investment, rather than saving.
[3] Exceptions include Sachs, Tornell, Velasco (1995) and Bussiere and Mulder (1999a,b), who use a continuous dependent variable.
[4] See Berg and Pattillo (1999) and Berg, Borenzstein and Pattillo (2004) for a review.

to withdraw their investments, therefore increasing the risk of a future crisis. In this case, the lagged dependent variable would have a positive sign. In the long run, the effect could again work in both directions: a country that is accustomed to crises can be deemed inherently more vulnerable by investors while, by contrast, a country that has been hit by a crisis may benefit from higher vigilance by policy makers and investors, thus avoiding further crises.[5] The question of state dependence has obvious policy implications: it would mean that countries that have been hit by a crisis in the past may be, as a result, more (or less, depending on the sign) vulnerable.

The second characteristic of existing models, which assume that the impact of all explanatory variables operates at the same lag, can also be questioned. Indeed, one would expect for instance that structural problems in the economy (such as deficiencies in the banking sector) have an effect in the long run, whereas liquidity problems can be expected to have an impact in the shorter run.

The aim of the present paper is to revisit these two assumptions. The issue of the lagged dependent variable is tackled using for the first time in the context of currency crises a dynamic discrete choice model. This has not been attempted before although a recent working paper (Georgievska et al., 2006), indicates that this issue should be tackled in future research.[6] Such models were developed in particular by Heckman[7] and further enhanced by Honoré and Kyriazidou (2000). Their basic insight is that not only independent variables, but also the lagged dependent variables, are relevant: omitting to account for possible state dependence can yield biased estimates. However, the estimation of state dependence is complicated in the presence of idiosyncratic effects, as what appears to reflect state dependence may in fact reflect the presence of (unobserved) individual effects, which Heckman (1981a) refers to as "spurious state dependence". The motivation for idiosyncratic effects comes from the fact that no model, no matter how rich, can take all country characteristics into account. In the present context, individual fixed (country) effects may reflect non-observable characteristics like, for instance, the openness of a country to foreign investment, the specificity of its political system or its legal institutions, etc.[8] The present paper therefore investigates the role of country fixed effects using a conditional logit model. The two issues mentioned above (state dependence and individual effects) are closely related. For example, if a country is characterized by a large number of crises (for given vulnerability indicators), one may think that this is due to either (i) the fact that the first

[5] See for instance Bernanke (2005): "In response to these crises, emerging-market nations were forced into new strategies for managing international capital flows.(…) For instance, (…) some Asian countries, such as Korea and Thailand, began to build up large quantities of foreign exchange reserves. (…) These "war chests" of foreign reserves have been used as a buffer against potential capital outflows".

[6] "Another recommendation for future research concerns the specification of the econometric model itself. E.g. one could model a dynamic discrete choice model, in order to account formally for state dependency effects" (p. 10).

[7] A thorough discussion of discrete choice models can be found in Heckman (1981a, b, c). Heckman (1981a) discusses the relation between heterogeneity and state dependence (see in particular p. 150 onwards) and refers to earlier work on the issue.

[8] Some attempt has been made at estimating the role of political variables in a cross-sectional context, see for instance Bussière and Mulder (1999a). However, although political variables can increase the goodness of fit of the model, substantial cross-country heterogeneity remains and calls for the use of fixed effects.

crisis rendered this country more vulnerable to future shocks or (ii) that an unobserved component makes this country more prone to crises. In order to account for this possibility, this paper presents results from four specifications: a static model, a dynamic model, a static model with fixed effects and a dynamic model with fixed effects. Results indicate that positive state dependence matters (there is a risk for a given country to experience crises repeatedly), but only in the short run (less than a year). In addition, one needs to use either fixed effects or a dynamic model: both yield results similar to each other, and different from the simple static model. It seems also that the fixed effect model may be preferred to the dynamic model to avoid the spurious dependence result.

The second intended contribution of the present paper is related to the time length at which vulnerability indicators impact the dependent variable. This issue seems to have been overlooked by the existing literature, although it also has important policy implications. Often, policy actions taken at a given time can have an effect only in the medium to long run (a typical example is debt issuance, another is reforms of the banking sector), whereas other types of action will yield an effect immediately (e.g. borrowing reserves). Results indicate that liquidity measures such as the short-term debt to reserves ratio and contagion both have a very short-run impact (four and six months, respectively), whereas a measure of banking sector fragility such as the so-called lending boom variable has a longer-run impact (about a year), and a measure of over-appreciation an even longer-run impact (two years).

The fact that lags can be long or short also influences the way one intends to "predict" currency crises. If the aim is to predict the precise timing of crises, the estimation must be made by using the left-hand side crisis index at time T and lagged explanatory variables. However, this goal appears to be very difficult to reach[9], so that one may have to go for a second best and attempt to predict whether crises can happen in a given time window (e.g. one year), by using a forward index[10]. Bussiere and Fratzscher (2006)[11] thus used a transformed crisis index equal to one in the 12 months preceding crises and asked a related but different question: are economic fundamentals different in these 12 months than at other times? The present paper discusses and compares these different approaches. Overall, there seems to be a trade-off: using a forward index improves the goodness of fit, but this comes at a cost, since inference on the timing is lost. Using a contemporaneous index therefore complements the other approach as it allows tackling issues such as state dependence and the timing of the various early indicators, but comes with the cost of a lower goodness of fit. The results presented here have important policy implications. First, state dependence suggests that vigilance must not decrease after a first crisis has happened as it may be

[9] See also Peltonen (2006) and the references therein.
[10] "Forwarding" the crisis index in order to define a time window is relatively common in the literature on financial crises, see for instance Fuertes and Kalotychou (2004) as well as the references therein.
[11] In fact the paper used three regimes in a multinomial logit framework, which was shown to increase the fit of the model compared with a two-regime model. While this technique proved useful to obtain a good fit, it does not specifically address the issue of state dependence and does not allow for different time lags across explanatory variables, which are the two objectives of the present paper.

followed by other crises. Second, some indicators signal crises in the very short run, which calls for a particularly quick policy response. This is the case of the short-term debt to reserves liquidity ratio and of financial contagion.

The rest of the paper is organized as follows: Section 2 presents the data and sketches some stylized facts; Section 3 reviews the dynamic discrete choice models; Section 4 presents the results based on a raw crisis index and Section 5 the results based on the transformed crisis index; Section 6 concludes.

2. Presentation of the sample and stylized facts

2.1. The sample: 27 countries, 7 years of monthly observations

As crises are a relatively rare event, a country by country estimation would rapidly run out of degrees of freedom. Using observations across different countries and throughout time allows one to find common characteristics across crisis episodes: Brazil experienced a so-called "lending boom" before it succumbed to the Tequila crisis in 1995, but was the lending boom really responsible for the crisis? The other indicators usually included in early warning systems might have been a potential culprit too. To answer this question, we need to check whether other crisis-affected countries also experienced a "lending boom" before a crisis, controlling for other factors. The aim of the exercise is therefore find "common empirical regularities" across crises. Such common regularities must not be confused with true causal relationships, which would be very difficult to establish, as already noted in Peltonen (2006). Pooling together the experience of several countries increases the number of observations but comes at the cost of imposing slope homogeneity across countries or regions.[12]

Increasing the number of observations by increasing the number of countries and the time length of the data allows testing for more variables, but it comes at a cost: the countries considered need to be sufficiently homogeneous that we can reasonably expect to find common fundamentals behind crises. In the current context this yields a panel of 27 countries listed in the country Appendix (see Table 9). The data are at a monthly rather than quarterly frequency as currency crises sometimes unfold in a couple of weeks. Estimation results start in 1994M1 because the period immediately before saw two important mutations that could seriously bias the results: firstly many Latin American countries moved away from hyperinflationary regimes, and secondly many Eastern European countries were still proceeding with transition towards a market economy. In spite of this rather late start the panel is still unbalanced because some of the countries that emerged from the former USSR went through a period of adjustment characterized

[12] Several papers have tested for slope homogeneity. For instance, Bussiere and Fratzscher (2006) run out-of-sample forecasts where they include only observations until the Asian crisis and check whether the estimated model can explain subsequent crises. The good out-of-sample performance suggests that the same model applies to different countries/episodes. Peltonen (2006) finds differences between Latin America and Asia, but his sample goes back to the 1980s. The present sample is more homogeneous as it considers the 1990s only.

by high instability of the exchange rate that cannot be confused with the kind of currency crises experienced by the other countries. Overall, estimations are computed over roughly 2000 observations.

2.2 Definition of the variables

A currency crisis is usually defined as a sharp depreciation of the exchange rate.[13] However, it also refers to situations when pressure on the exchange rate is so high that it leads to a strong rise in interest rates and/or to a loss in international reserves. Here, the dependent variable, CI (for crisis index) refers to the second definition and is computed in two steps. In the first step, a so-called "exchange market pressure index" is calculated as a weighted average of the change in the real effective exchange rate, in reserves and in real interest rates (see Appendix)[14]. Second, this variable is transformed into a binary variable using as cut-off point two standard deviations. Transforming a continuous variable into a discrete one obviously involves a loss of information. However, this comes with the advantage that the (by now very comprehensive) theoretical framework of discrete choice models can be used. In addition, the loss of information may not be so large if non-linearities are present in the data[15] (which turns out to be the case here) and if the underlying continuous variable is noisy.

The variables used as early warnings are defined as follows. The first variable is the debt ratio. Debt ratios appear to be among the most often used indicators of currency crises, in particular the ratio of short-term debt (as defined by the Bank of International Settlements) to international reserves: the higher short-term debt, the higher the probability that the borrower will default.[16] In the same way, the lower the level of international reserves held by the monetary authorities, the more difficult is will be for the authorities to defend the value of a currency in case of an attack. The appropriate way to scale these two variables is to use the so-called Greenspan-Guidotti ratio (defined as short-term debt divided by international reserves). A rise in this ratio can come from either a rise in debt or a drop in reserves, which is exactly what the "Greenspan-Guidotti rule" states: reserves should entirely cover the amount of debt that can be sold short-term by investors in case of an attack. A long-term debt ratio can be computed in the same fashion.

The second variable is the current account, which has been identified in a number of papers as a key variable for the analysis of crises in emerging markets (see in particular Milesi-Ferretti and Razin, 1998). The current account needs to be scaled to account for the different size of the economy; the approach chosen here consisted in scaling the current account balance with GDP. The third variable is the government budget balance which, like the current account balance, is

[13] According to Wikipedia, "a currency crisis (also known as a financial crisis) occurs when the value of a currency changes quickly, undermining its ability to serve as a medium for exchange or a store of value".
[14] See also Frankel and Rose (1996), Sachs, Tornell and Velasco (1996) or Eichengreen, Rose and Wyplosz (1996) for a discussion of crisis indices. Market pressure indices were first introduced by Girton and Roper (1977).
[15] I am grateful to H. Lütkepohl for pointing this out to me.
[16] See for instance Bussiere, Fratzscher and Koeniger (2006) for a theoretical and empirical investigation.

divided by GDP. A large government deficit could signal a crisis based on Generation I models of crises (Krugman, 1979). The fourth variable measures the extent of the real exchange rate over-appreciation before a crisis. To investigate this issue, over-valuation was defined as deviation of the real effective exchange rate[17] from a linear trend.[18]

The fifth variable is the so-called "lending boom" measure. It is designed to capture weaknesses in the financial system. As the exact number of non-performing or bad loans in the economy is not directly observable for obvious under-reporting reasons, the literature has searched proxies. The so-called "lending boom", that measures the increase of the credit to the private sector (CPS) over a 2 or 3 year period, can be useful in this respect (see Tornell, 1999). Here the measured is transformed as a deviation from a one year average (to avoid base effects) with a two year lag:

$$LB_t^i = \left(\frac{CPS_t^i}{GDP_t^i} - \overline{\frac{CPS_{t-24}^i}{GDP_{t-24}^i}} \right) * 100 \tag{1}$$

Where:

$$\overline{\frac{CPS_{t-24}^i}{GDP_{t-24}^i}} = \frac{1}{12} \sum_{k=0}^{11} \frac{CPS_{t-24-k}^i}{GDP_{t-24-k}^i} * 100 \tag{2}$$

The sixth variable is the real growth rate. The growth rate of the real GDP is a crucial variable because it is more likely that a government lets the currency devalue in case of low growth for at least two reasons. First a slow-growing economy has fewer resources to defend itself against an attack, and second political economy reasons will make it more likely that the government devalues to gain competitiveness and boost growth:

$$GROWTH_T^i = \frac{GDP_t^i - GDP_{t-12}^i}{GDP_{t-12}^i} * 100 \tag{3}$$

The seventh variable used in the present study attempts to account for contagion across emerging markets. The contagion variables used here follow the definition of Fratzscher (1998). Contagion across countries is a well-known fact, and is assumed to take different channels, among others financial and trade linkages. As the former are generally found significant whereas the latter are not (see Bussière and Fratzscher, 2006), the present paper focuses only on financial contagion.[19]

Finally, the predictive power of market based indices was also tested. Do financial markets anticipate crises? Face value evidence would tend to show the opposite, as the Asian crisis for instance was largely unexpected. To test whether market values of key stock indices (here, Datastream indices) can provide any information, this paper tests variables equal to a 12 month

[17] See Desruelles and Zanello (1997) for a description of the methodology.
[18] Several alternative measures have been used, such as the deviation from a quadratic trend or simply the rate of change in the preceding 12 or 24 months, with broadly similar results.
[19] See also Pesaran and Pick (2006) for a recent analysis of contagion, with a focus on European interest rate spreads during the ERM crisis.

percent change of three indices: a broad market index, and two sub-indices on banks and financial institutions.

2.3. Stylized facts

Independent variables

Before turning to the model, let us gain evidence from stylized facts by looking at the variables outlined in the preceding section. Table 1 below presents the values of these variables on average (column 1), and compares these values with the average computed one year before crises (column 2), and outside crises (column 3).[20]

Table 1: Average Values of the Explanatory Variable Ahead of Crises

	(1) Average	(2) Average T-1 to T-12	(3) Average T-13 to T-24
Short-term debt / reserves	83.68	103.58	103.24
Current account / GDP %	-1.44	-2.84	-2.85
Government balance / GDP %	-1.36	-0.85	-0.86
Real effective exchange rate / trend %	0.75	6.92	5.71
Lending boom %	17.75	37.37	22.63
Growth rate %	4.20	3.39	4.38
Financial contagion	0.37	1.39	-1.30
Datastream Index, Banks	23.49	13.25	31.63
Datastream Index, Market	27.77	13.24	27.92
Datastream Index, Financial Institutions	20.84	9.23	28.76
Trade balance / GDP %	-3.58	-5.03	-5.34
Total debt (locational concept) / reserves	176.22	214.27	215.64
Total Debt (consolidated Concept) / reserves %	158.36	201.23	196.09
Reserves, 12 months growth rate	0.20	0.16	0.24
Reserves over exports, 12 months growth rate	0.09	0.07	0.07

Three key lessons can be learnt from Table 1. First, looking at Column (1), one can notice that the 27 countries included in the table are relatively fast growers since their growth rate was on average equal to 4.2% in the period covered in the sample (starting 1994M1). Their reserves covered most of short-term debt (although the average figure hides important differences between very open countries like in South East Asia or Latin America and countries like India, China, and some Eastern European countries). They generally ran moderate current account (-1.44%) and government (-1.36%) deficits.

The second lesson to draw from the table arises by comparing column (1) (average values) and (2) (average in the 12 months preceding the crisis). The picture of a typical crisis country emerges as follows:[21] its exchange rate is markedly over-appreciated with respect to trend, its

[20] Further detail on how the variables were computed can be found in the Country and Data Appendix. The values of Table 1 differ from Table 11 in Bussière and Fratzscher (2002), because the samples are different –in the latter, only the values of 20 “core” countries, more open to foreign investment. It is noteworthy that including countries like India has a sizable effect on the average debt to reserves ratio.

[21] Of course one should be cautious in interpreting these numbers are they represent an unconditional correlation.

current account and trade balances record a deficit, the levels of its short-term and long-term debt are above the level covered by international reserves. The government deficit on the other hand is not necessarily larger: it is now a well established fact in the literature that crisis-affected countries did not have larger government deficits (in fact many of them had government surpluses). The higher value of the lending boom variable indicates that the crisis countries probably experienced excessive bank lending in the period prior to the crisis. The Datastream indices show that the market values of banks and especially financial institutions are moderating, similar to the markets as a whole.

The third lesson to draw from the table arises from the comparison of column (2) and (3). One striking feature is that the problems identified in the previous paragraph often date back longer than generally perceived. For variables like the debt ratios, the current account deficit, or exchange rate over-valuation, the deterioration occurred already in the period between 12 and 24 months before the crisis. For other variables, the deterioration happened in the 12 months preceding the crisis, sometimes even at a shorter lag; this is the case of the growth rate, the "lending boom", and the market indices.

The dependent variable

The dependent variable CI was defined in section 2. The Appendix shows as an example the charts for some of the countries included in the sample; each chart plots the exchange rate index and the corresponding binary crisis index (CI). Three countries have never experienced a crisis: Hungary, Latvia and the Slovak Republic. Many of the East Asian countries experienced only one crisis whereas many Latin American countries experienced more than one crisis.

3. Dynamic discrete choice model: presentation of the model

The object of this section is not to introduce new considerations on logit models but to present the models that will be estimated in the following two sections. It closely follows Wooldridge (2001) and Baltagi (2001), and proceeds sequentially by discussing the basic static model (1), individual effects (2) and the dynamic model (3).

3.1. Basic review of binary-variable models

Let us first detail the notation that will be used in the rest of this section.

Introductory notation

The sample contains N countries i={1,2,…N}, observed during T periods t={1,2,…T}. Each observation is then a country/month. The aim of the model is to estimate the probability that a crisis happens, i.e. that the crisis index equals one. This probability is noted P:[22]

[22] Time and country indices are omitted in this section to simplify notation.

$$Y = \begin{cases} 1 \quad with \quad probability \quad \Pr(Y=1) = P \\ 0 \quad with \quad probability \quad \Pr(Y=0) = 1-P \end{cases} \tag{4}$$

A set of K independent variables are observed across the N countries and the T periods; they are collected in a matrix X whose dimension is therefore NT*K. In a static model the objective is to estimate the effect of the indicators X on the probability P of a crisis Y. Let us denote γ the vector of K marginal effects:

$$\gamma = \frac{dP}{dX'} \tag{5}$$

As the first, simplest model is the linear probability model, let us review it briefly before turning to the logit model.

The linear probability model

In a linear probability model, P is a linear function of X:

$$P = F(X\beta) = X\beta \tag{6}$$

in which β is a K*1 column vector of parameters and X includes a constant term. Thus:

$$Y = X\beta + \varepsilon \tag{7}$$

In the linear probability model the effect of the indicators on the probability of a crisis is therefore linear (marginal effects are equal to the coefficients):

$$\gamma = \frac{dP}{dX'} = \beta \tag{8}$$

The logit model

Probit and logit models are generally similar so the choice between them is a matter of convenience. Since the logistic distribution has fatter tails than the cumulative normal it seems more appropriate for an application to currency crises in view of the stylized facts outlined in section 2. In addition, as next section will use fixed effects, which is possible in a logit model but has no counterpart in a probit model, estimation uses a logit model.

The probability of a given event, here a currency crisis, is given by:

$$\Pr(Y=1) = F(X\beta) = \frac{e^{X\beta}}{1+e^{X\beta}} \tag{9}$$

Equation 9 shows that the independent variables have a non-linear effect on the probability that a crisis bursts out. This property of the model makes it well suited to deal with currency crises because the theoretical literature, evidence from stylized facts and traditional wisdom among policy makers suggest the presence of strong non-linear effects. One key assumption is that the variables used as indicators are exogenous; the present paper therefore follows standard practice (see Peltonen, 2006) to lag the explanatory variables.

3.2. Individual effects

The reason for country effects

In spite of the great care exercised in selecting homogeneous countries and a large set of variables, the presence of country effects is still likely. Some characteristics of the different countries included in the sample are not observable, or not easily captured in the various variables one can compile. Two examples can illustrate this point. First, some countries impose restrictions on their capital account that may have consequences on their ability to avoid crises. One could go in search of a proxy but it is not clear how effective it will be. A second example relates to political economy considerations. Politically unstable countries are known to be more prone to crises. In fact there is some empirical evidence of this fact, as demonstrated in Bussiere and Mulder (1999) that tests a set of political variables. However, even these political indicators cannot capture everything: the judicial system, contract enforcement, law and order, or other institutional characteristics may be relevant to explaining the occurrence of crises. As a consequence of the omission of such elements, the model can permanently underestimate or overestimate the probability of a crisis in a given country.

Fixed and random effects

Individual (country) effects can be incorporated into the model by using fixed or random effects. As the two names suggest, fixed effects assume that the country effect is "fixed" and estimable, whereas random effect assume that country effects have a distribution. With fixed effects only the "within" information is used in the model (losing the "between" information); see Wooldridge (2001), Chapter 15, for a discussion. Although random effects represent a more efficient combination of within and between information, they come at a cost: random effects models assume that the country effects are not correlated with the independent variables. This assumption seems over-stretched here: if the political setting or capital account openness are relevant to crisis vulnerability, we might also expect that they have an influence on the other variables, particularly the current account deficit, the level of public debt, or the state of the financial sector. For this reason fixed effects appear to be a better choice.

The conditional logit model

In the presence of fixed effects equation (10) becomes:

$$\Pr(Y_i^t = 1 \mid X_i^t, \alpha_i) = \frac{e^{\alpha_i + X_i^t \beta}}{1 + e^{\alpha_i + X_i^t \beta}} \qquad (10)$$

In traditional panel data (i.e. when the left-hand side is not binary), fixed effects can be estimated using country dummies (a least square dummy variable model), using deviations from country specific means, or computing differences. In the case of the logit model a convenient solution was proposed by Chamberlain (1980), who suggested maximizing the conditional likelihood function:[23]

[23] The discussion follows Baltagi (2001), p. 206.

$$L_C = \prod_{i=1}^{N} P\left(Y_i^1, Y_i^2, ..., Y_i^T \mid \sum_{t=1}^{T} Y_i^t \right) \quad (11)$$

The intuition for this approach can be understood with the simple example in which T=2. As the example is now debated in many textbooks, let us sketch the reasoning below. There are four possible sequences: {(0,0), (0,1), (1,0), (1,1)}. The two sequences (0,0) and (1,1) do not contribute to the likelihood because trivially:

$$P\left(Y_i^1 = 0, Y_i^2 = 0 \mid Y_i^1 + Y_i^2 = 0\right) = P\left(Y_i^1 = 1, Y_i^2 = 1 \mid Y_i^1 + Y_i^2 = 2\right) = 1 \quad (12)$$

What remains is therefore the observations for which the outcome has changed (as usual using fixed effects):

$$P\left(Y_i^1 = 1, Y_i^2 = 0 \mid Y_i^1 + Y_i^2 = 1\right) = \frac{e^{X_i^1{}'\beta}}{e^{X_i^1{}'\beta} + e^{X_i^2{}'\beta}} = \frac{1}{1 + e^{\left(X_i^2 - X_i^1\right)'\beta}} \quad (13)$$

$$P\left(Y_i^1 = 0, Y_i^2 = 1 \mid Y_i^1 + Y_i^2 = 1\right) = \frac{e^{X_i^2{}'\beta}}{e^{X_i^1{}'\beta} + e^{X_i^2{}'\beta}} = \frac{e^{\left(X_i^2 - X_i^1\right)'\beta}}{1 + e^{\left(X_i^2 - X_i^1\right)'\beta}} \quad (14)$$

The two probabilities expressed in (13) and (14) are a function of the independent variables only, the country effects cancelling out. In a probit model the country effects would not cancel out. On the other hand a probit model would allow for random effects, but these methods become computationally difficult for large T (here T is above 80), and above all random effects assume that country effects are not correlated with independent variables, which does not seem reasonable in the present context.[24]

3.3 Dynamic discrete choice model

The framework outlined in the previous section can be extended to a dynamic model. Several contributions have played a role. First, Chamberlain (1985) extended the model to lagged dependent variables but no exogenous variable. Honoré and Kyriazidou (2000) extended Chamberlain's fixed effects logit to the case where there are also exogenous explanatory variables. Denoting P_i^0 the probability to observe the initial period outcome Y_i^0 , we have:

$$P\left(Y_i^0 = 1 \mid X_i^0{}', \alpha_i\right) = P_i^0\left(X_i^0{}', \alpha_i\right) \quad (15)$$

and

$$P\left(Y_i^t = 1 \mid X_i^t{}', \alpha_i, Y_i^0, ..., Y_i^{t-1}\right) = \frac{e^{X_i^t{}'\beta + \gamma Y_i^{t-1} + \alpha_i}}{1 + e^{X_i^t{}'\beta + \gamma Y_i^{t-1} + \alpha_i}} \quad (16)$$

The assumptions of the model by Honoré and Kyriazidou are the following: the variables in X are strictly exogenous, the errors are IID with a logistic distribution and independent of X, of the fixed effects and of the initial value of variable Y. They propose an estimation method for the

[24] If, as argued above, fixed effects arise because of government regulations such as capital account restrictions, some of the explanatory variables are very likely to be affected, like the current account.

case when the panel contains only four observations per unit and consider extensions to the more general case of longer panels and to the case with more than one lag of the dependent variable. However, this extension is subject to some assumptions, in particular on the explanatory variables, which are not satisfied here.[25]

The general formulation by Heckman (1981) is more encompassing. Adapting the notation to the present setting it is:

$$EMPI_i^t = X_i^t \beta + \sum_{j=1}^{\infty} \gamma^{t-j} Y_i^{t-j} + \sum_{j=1}^{\infty} \lambda^{t-j} \prod_{l=1}^{j} Y_i^{t-l} + G(L)\ EMPI_i^t + \varepsilon_i^t \qquad (17)$$

In equation (17) the first two terms were defined previously. The third term corresponds to state dependence: in the words of Heckman "this term is introduced to capture the notion that, once an individual is in a state, an accumulation process begins".[26] The last term was introduced in the Heckman model to capture the notion of habit persistence, the utility level playing the role of the EMPI here, G(L) denoting a general lag operator of order H. As this fourth term is difficult to interpret in the context of currency crises, it will be left out in the empirical section. Similarly, the third term will not be included here[27] so that the model is more simply expressed:

$$EMPI_i^t = X_i^t \beta + \sum_{j=1}^{\infty} \gamma^{t-j} Y_i^{t-j} + \varepsilon_i^t \qquad (18)$$

In the end the specification is therefore

$$P(Y_i^t = 1) = \frac{e^{X_i^t \beta + \sum_{j=1}^{\infty} \gamma^{t-j} Y_i^{t-j}}}{1 + e^{X_i^t \beta + \sum_{j=1}^{\infty} \gamma^{t-j} Y_i^{t-j}}} \qquad (19)$$

3.4. Heterogeneity and state dependence

One of the key contributions of Heckman (1981a, b, c) was to show that the issue of heterogeneity across units interferes with the question of state dependence. Indeed, his study on the job market of married women showed that when heterogeneity is neglected, the effect of past choices is overstated. To take an example from the present context, Brazil is a country that is known to have experienced repeated crises, whereas Hungary has never had one - in the sample described in section 2. To which factors should one attribute this difference? First of all, the exogenous variables included in the estimation should control for the countries' fundamentals. Second, country fixed effects capture those characteristics that are omitted or non-observable. Third, the lagged dependent variable aims at incorporating state dependence. Yet, clearly, the last two elements (fixed effects and state dependence) are difficult to disentangle.

[25] See also Kaiser and Kongsted (2004) for a recent application and discussion.
[26] Heckman (1981a) p. 122. The way crises have been defined (see also charts in the appendix) implies that crises are typically separated rather than appearing in succession so the notion of accumulation in states is not directly relevant here.
[27] As argued in the conclusion, this can be pursued in future research.

4. Results based on a contemporaneous crisis index: a month-to-month model

To address the issues outlined in Section 3, Section 4 proceeds sequentially. It starts from a static model (1), then introduces fixed effects (2), then moves to the dynamic model without fixed effects (3), before combining a dynamic model with fixed effects (4). The reason of this sequential approach is to show that the conclusions differ substantially if fixed effects are omitted or when the model is made dynamic.

4.1. Evidence from the static model

Table 2 presents the results obtained with a sub-sample of the variables in the database, independent variables being lagged one month. Column (1) includes on the right hand side the independent variables used in the core model of Bussière and Fratzscher (2002). Although the sample and the dependent variable are different, all the coefficients have the correct sign and are significant at the conventional levels. The two exceptions are the current account and the growth rate, but that should not come as a surprise in view of the stylized facts outlined in Section 2: whereas Bussière and Fratzscher (2002) focus on a relatively long period of time (12 months), the results presented in Table 2 are performed on a short horizon (a month-to-month forecast).

Columns (2) and (3) show that long-term debt ratios are informative as well. The results obtained with locational and consolidated debt are very close, so there is no evidence to support the general view that the latter concept is more informative than the former (as was put forward on the eve of the 2001 Argentine crisis).

Column (4) shows that the government budget balance enters with a positive sign in the equation and is significant at the 10% level. A positive sign implies that a higher surplus increases the risk of a crisis, a somewhat counter-intuitive outcome that contradicts first-generation types of crises (Krugman, 1979). This fact is well documented and has been recognized as a failure of Generation I models to explain the crises in the 1990's successfully (Krugman, 1998). This fact could however indirectly support Generation II models (Obstfeld, 1984), in which political economy considerations and moral hazard play an important role.

The last three columns test the relevance of stock indices: for the whole market (5), for a sub-index on banks (6), and for a sub-index of financial institutions (7). The coefficients on all three variables enter the equation with the expected (negative) sign but do not cross the 10% significance level. Contagion was excluded from this regression to avoid multi-collinearity (the lending boom, which indirectly measures the health of the financial sector, could also possibly interfere with the indices; yet, removing it did not change the conclusion).

Overall, a higher deviation of the exchange rate from its trend, a faster "lending boom", higher debt to reserves ratios, as well as contagion from other financially integrated countries increase the probability of a crisis; conversely a rise in the current account surplus (a reduction of the deficit), and stronger domestic growth reduce the probability of a crisis. The next question to investigate is how these conclusions are affected by the use of a dynamic model and by the presence of fixed effects.

Table 2: Results using the static model with no fixed effects.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Exch. Rate, dev. from trend	0.037 0.014**	0.036 0.013***	0.033 0.012***	0.025 0.009***	0.036 0.021*	0.042 0.016***	0.038 0.015***
Lending boom	0.006 0.001***	0.006 0.001***	0.006 0.001***	0.006 0.001***	0.002 0.007	0.008 0.006	0.008 0.006
Short-term debt / Reserves	0.004 0.001***	-	-	0.0035 0.002**	0.003 0.002*	0.003 0.002*	0.003 0.002*
Total debt / Reserves (locational concept)	-	0.002 0.001**	-	-	-	-	-
Total debt / Reserves (consoli-dated concept)	-	-	0.003 0.001***	-	-	-	-
Current account surplus	-0.007 0.021	-0.002 0.019	-0.009 0.022	-	-0.021 0.022	-0.024 0.026	-0.022 0.024
Government surplus	-	-	-	0.082 0.046*	-	-	-
Financial contagion	0.043 0.023*	0.043 0.023*	0.043 0.024*	0.035 0.023	-	-	-
DS index, total market	-	-	-	-	-0.010 0.015	-	-
DS index, banks	-	-	-	-	-	-0.016 0.012	-
DS index, financial Institutions	-	-	-	-	-	-	-0.016 0.014
Growth rate	-0.036 0.030	-0.034 0.029	-0.023 0.031	-0.052 0.026**	0.003 0.034	0.015 0.030	0.019 0.032
Constant	-4.306 0.278***	-4.239 0.278***	-4.451 0.249	-4.050 0.284***	-4.022 0.287	-4.269 0.361***	-4.345 0.405
# obs	1931	1931	1931	1866	1444	1373	1373
Pseudo R^2	0.059	0.057	0.064	0.054	0.045	0.067	0.069
Log likelihood	-208.03	-208.48	-206.87	-204.11	-164.27	-151.82	-151.62

*Independent variable is the crisis index defined in Section 2. Standard errors in small font, robust estimates using countries as clusters *, **, and *** indicate significance at the 10%, 5%, 1% level respectively.*

4.2. Evidence from the static model with fixed effects

Before turning to the dynamic model, Table 3 shows the results performed with the same variables as in Table 2 using the fixed effect (conditional logit) model. A likelihood ratio test led to the rejection of the hypothesis that all country fixed effects were equal to zero (although the p-value of the test was close to 10%). Not all the 27 countries in the sample are kept in the conditional logit model because those countries that never experienced a crisis are dropped out (the country effect perfectly explains the 0 outcome). One striking outcome is that results are very close to those of Table 2: the variables that were significant in Table 2 are also significant in Table 3, the coefficients being most of the time not significantly different from each other. However, some important differences arise. For instance, in the first column, the coefficient of short-term debt is twice as high using the fixed effect model compared with the standard model. In addition, the coefficient of the current account becomes significant when using fixed effects, which shows the importance of taking into account fixed effects when estimating such models.

Table 3: Results using the static model with fixed effects.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Exch. Rate, dev. from trend	0.036 0.0163**	0.043 0.0170***	0.045 0.0167***	0.032 0.0157**	0.046 0.0207**	0.045 0.021**	0.042 0.021**
Lending boom	0.006 0.003**	0.006 0.003**	0.005 0.003**	0.006 0.0027**	-0.007 0.009	0.003 0.009	0.003 0.009
Short-term debt / reserves	0.008 0.003***	-	-	0.009 0.0026***	0.009 0.003***	0.007 0.003***/	0.007 0.003***
Total debt / reserves (loc. concept)	-	0.004 0.001***	-	-	-	-	-
Total debt / reserves (cons. concept)	-	-	0.006 0.002***	-	-	-	-
Current account surplus	-0.079 0.051*	-0.08 0.05*	-0.077 0.05*	-	-0.110 0.069*	-0.135 0.080*	-0.141 0.082*
Government surplus	-	-	-	0.158 0.120	-	-	-
Financial contagion	0.043 0.021**	0.045 0.021	0.042 0.021**	0.039 0.021**	0.05 0.024*	0.04 0.023*	-0.015 0.006***
DS index, total market	-	-	-	-	-0.008 0.005***	-	-
DS index, banks	-	-	-	-	-	-0.014 0.005***	-
DS index, financial institutions	-	-	-	-	-	-	-0.015 0.006***
Growth rate	-0.05 0.037	-0.049 0.037	-0.0465 0.037	-0.058 0.037	-0.027 0.046	-0.016 0.049	-0.013 0.049
Number of groups	22	22	22	22	18	17	17
# obs	1655	1655	1655	1587	1438	1367	1367
Log likelihood	-164.75	-164.15	-162.85	-163.34	-129.93	-119.34	-118.95

*Independent variable is the crisis index defined in Section 2. Standard errors in small font, robust estimates using countries as clusters *, **, and *** indicate significance at the 10%, 5%, 1% level respectively.*

4.3. Evidence from the dynamic model, no fixed effects

To see the effects of working with a dynamic model, Table 4 shows the results performed with the same variables as in Table 2, and including up to six lags of the dependent variable (more lags were not insignificant).

Table 4: Results using a dynamic model, no fixed effects.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crisis index, lag 1	0.588 0.677	0.633 0.676	0.568 0.671	0.611 0.686	0.612 0.713	0.446 0.713	0.417 0.718
Crisis index, lag 2	0.575 0.773	0.601 0.772	0.534 0.779	-0.271 1.059	0.581 0.793	0.429 0.791	0.418 0.793
Crisis index, lag 3	-0.317 1.085	-0.299 1.08	-0.304 1.083	-0.374 1.089	-0.332 1.111	-0.495 1.104	-0.468 1.103
Crisis index, lag 4	0.949 0.707	0.966 0.707	0.973 0.703	0.783 0.712	1.097 0.744	0.375 0.850	0.396 0.851
Crisis index, lag 5	1.874 0.575***	1.883 0.576***	1.909 0.569***	1.583 0.575***	1.746 0.663***	1.636 0.655***	1.647 0.658***
Crisis index, lag 6	1.600 0.618***	1.600 0.618***	1.628 0.612***	1.344 0.614***	2.036 0.674***	1.893 0.677	1.897 0.680
Exch. rate, dev. from trend	0.047 0.014***	0.049 0.0137***	0.047 0.130***	0.037 0.014***	0.053 0.018***	0.056 0.019***	0.052 0.019
Lending boom	0.003 0.003	0.003 0.003	0.003 0.003	0.004 0.003	-0.0004 0.006	0.005 0.006	0.006 0.007
Short-term debt / reserves	0.004 0.001***	-	-	0.003 0.002**	0.004 0.002**	0.004 0.002	0.004 0.002
Total debt / reserves (locat. concept)	-	0.0017 0.001***	-	-	-	-	-
Total debt / reserves (consoli-dated concept)	-	-	0.003 0.001***	-	-	-	-
Current account surplus	-0.022 0.024	-0.017 0.0238	-0.0251 0.0254	-	-0.035 0.027	-0.036 0.028	-0.036 0.028
Government surplus	-	-	-	0.051 0.060	-	-	-
Financial contagion	0.032 0.023	0.032 0.023		0.029 0.023	-	-	-
DS index, total market	-	-	-	-	-0.006 0.005	-	-
DS index, banks	-	-	-	-	-	-0.011 0.005**	-
DS index, financial Institutions	-	-	-	-	-	-	-0.011 0.005**
Growth rate	-0.004 0.032	-0.003 0.032	0.007 0.031	-0.024 0.032	0.035 0.037	0.048 0.038	0.051 0.038
Constant	-4.615 0.327***	-4.560 0.313***	-4.790 0.342***	-4.302 0.327***	-4.627 0.418***	-4.824 0.463	-4.868 0.463***
# obs	1919	1919	1919	1854	1441	1370	1370
Pseudo R^2	0.091	0.089	0.097	0.077	0.108	0.122	0.121
Log likelihood	-197.36	-197.64	-195.98	-195.52	-153.48	-142.99	-143.17

*Independent variable is the crisis index defined in Section 2. Standard errors in small font, robust estimates using countries as clusters *, **, and *** indicate significance at the 10%, 5%, 1% level respectively.*

The lagged dependent variable is significant only at lag 5 and 6. The correct interpretation of this result is of course not that crises always repeat themselves every 5 to 6 months, but rather that a few crisis episodes showed a specific pattern of a first crisis, followed by a second one six months afterwards. This clearly appears in the charts presented in the Chart Appendix: for Argentina in 2001, for Brazil following the 1995 Tequila crisis and in 1998, for Mexico at the end of 1994 and at the beginning of 1995, for Thailand and Indonesia in 1997/1998. In each case, one crisis followed another at an interval of around 6 months. Typically, in these instances, a first crisis is followed by a period of exchange rate overshooting, and then by a second, decisive crisis. Similarly as with the introduction of fixed effects, moving to the dynamic model has important consequences for the estimation results. In particular, the coefficient of the lending boom is no longer significant. Overall, however, these results are not very helpful in making predictions: first because the explanatory power is very low, and second because this six month interval does not fit for all countries (it would be misleading to believe that all crises happen this way, sometimes the interval is shorter, sometimes longer). Yet, an interesting feature of currency crises can be learnt through this exercise (the fact that crises can happen at a short time distance from each other).

4.4 Evidence from the dynamic model with fixed effects

Results of a dynamic model with fixed effects (Table 5) confirm the lessons learnt in the regressions presented in Tables 2, 3 and 4: the coefficients of the lending boom and of the contagion variables are no longer significant (as in Table 4), while the coefficient of the current account variable is now significant (as in Table 3). Intuitively, one can guess why the current account enters the regression significantly when using fixed effects: compared to the other variables, the current account tends to be relatively sluggish, especially at a monthly frequency, implying that a lot of the between information is actually driven by the fixed effects. One therefore needs to use the fixed effect estimator to fully capture the impact of the current account on the crisis variable. The reason why the coefficient of the lending boom variable is no longer significant is by contrast more difficult to explain at this stage, but will become clear in section 4.5.

4.5 Evidence from the standard model with lags

Last, Table 6 presents results using a standard logit model (static, without fixed effects), using many different lags (the coefficients and standard errors are presented in Chart 1 for four key variables). Specifically, the regression with the variables of the first column of Table 2-5 is run, changing the lags of the independent variables from 1 month to 24 months. The aim is to see whether results change a lot with longer lags.

Table 5: Results using a dynamic model with fixed country effects (conditional logit).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crisis index, lag 1	0.072	-0.018	-0.105	0.134	-0.036	-0.258	-0.363
	0.673	0.691	0.701	0.682	0.743	0.745	0.756
Crisis index, lag 2	-0.042	-0.218	-0.299	-1.049	-0.149	-0.516	-0.608
	0.826	0.881	0.909	1.218	0.891	0.902	0.913
Crisis index, lag 3	-0.727	-0.727	-0.748	-0.782	-0.698	-1.102	-1.104
	1.094	1.103	1.103	1.097	1.121	1.118	1.114
Crisis index, lag 4	0.499	0.446	0.452	0.344	0.693	-0.206	-0.221
	0.719	0.731	0.731	0.720	0.766	0.866	0.864
Crisis index, lag 5	1.589	1.571	1.575	1.354	1.615	1.298	1.276
	0.578***	0.584***	0.583***	0.570**	0.664**	0.664**	0.667
Crisis index, lag 6	1.495	1.523	1.530	1.229	2.057	1.738	1.733
	0.618***	0.623***	0.623***	0.609**	0.687***	0.686***	0.690
Exch. Rate, dev. from trend	0.048	0.055	0.057	0.042	0.599	0.055	0.052
	0.018***	0.018***	0.018***	0.017**	0.022***	0.022***	0.022
Lending boom	0.0019	0.001	0.001	0.002	-0.007	0.003	0.003
	0.0038	0.004	0.004	0.004	0.009	0.009	0.009
Short-term debt / reserves	0.009	-	-	0.011	0.011	0.009	0.009
	0.003***			0.003*	0.003***	0.004***	0.003
Long-term debt / reserves (locat. concept)	-	0.005	-	-	-	-	-
		0.001***					
Long-term debt / reserves (consoli-dated concept)	-	-	0.007	-	-	-	-
			0.002***				
Current account surplus	-0.08	-0.085	-0.082	-	-0.101	-0.128	-0.135
	0.055*	0.054	0.054*		0.003	0.085	0.087
Government surplus	-	-	-	0.164	-	-	-
				0.125			
Financial contagion	0.043	0.047	0.044	0.045	0.049	-0.056	0.052
	0.025*	0.026*	0.0259*	0.025*	0.028*	0.028**	0.028*
DS index, total market	-		-	-	-0.007	-	-
					0.005		
DS index, banks	-	-	-	-	-	-0.013	-
						0.006***	
DS index, financial institutions	-	-	-	-	-	-	-0.016
							0.006
Growth rate	-0.014	-0.013	-0.009	-0.030	0.011	0.016	0.020
	0.040	0.040	0.040	0.039	0.047	0.051	0.052
Number of groups	22	22	22	22	18	17	17
# obs	1649	1649	1649	1581	1438	1367	1367
Log likelihood	-157.46	-155.62	-154.24	-155.66	-123.00	-113.78	-113.34

*Independent variable is the crisis index defined in Section 2. Standard errors in small font, robust estimates using countries as clusters *, **, and *** indicate significance at the 10%, 5%, 1% level respectively.*

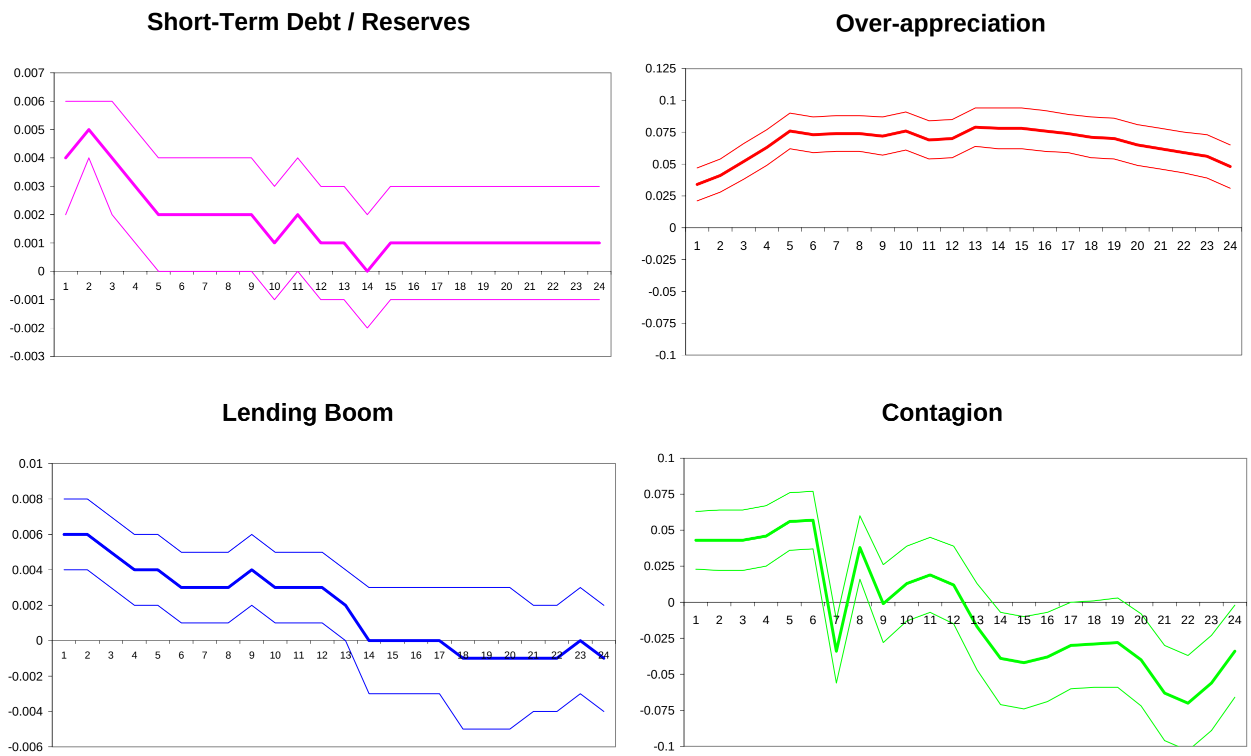
Table 6: Results using a standard model with increasing lags.

	REER	Lending Boom	S.T. debt / reserves	CA/GDP	Contagion	Growth
Lag 1	0.034	0.006	0.004	-0.007	0.043	-0.036
	0.013***	0.002***	0.002***	0.022	0.020**	0.030
Lag 2	0.041	0.006	0.005	-0.010	0.043	-0.022
	0.013***	0.002***	0.001***	0.023	0.021**	0.031
Lag 3	0.052	0.005	0.004	-0.011	0.043	-0.009
	0.014***	0.002***	0.002**	0.023	0.021**	0.032
Lag 4	0.063	0.004	0.003	-0.008	0.046	-0.012
	0.014***	0.002***	0.002*	0.024	0.021**	0.032
Lag 5	0.076	0.004	0.002	-0.005	0.056	-0.009
	0.14***	0.002***	0.002*	0.024	0.020***	0.032
Lag 6	0.073	0.003	0.002	-0.005	0.057	-0.011
	0.014***	0.002**	0.002	0.024	0.020***	0.032
Lag 7	0.074	0.003	0.002	-0.002	-0.034	-0.010
	0.014***	0.002*	0.002	0.024	0.022*	0.032
Lag 8	0.074	0.003	0.002	-0.002	0.038	-0.010
	0.014***	0.002*	0.002	0.024	0.022*	0.032
Lag 9	0.072	0.004	0.002	-0.002	-0.001	0.019
	0.015***	0.002**	0.002	0.025	0.027	0.032
Lag 10	0.076	0.003	0.001	0.004	0.013	0.032
	0.015***	0.002*	0.002	0.025	0.026	0.033
Lag 11	0.069	0.003	0.002	-0.003	0.019	0.033
	0.015***	0.002*	0.002	0.026	0.026	0.033
Lag 12	0.070	0.003	0.001	0.002	0.012	0.024
	0.015***	0.002*	0.002	0.026	0.027	0.033
Lag 13	0.079	0.002	0.001	0.008	-0.017	0.020
	0.015***	0.002	0.002	0.026	0.030	0.033
Lag 14	0.078	0.000	0.000	0.011	-0.039	0.014
	0.016***	0.003	0.002	0.026	0.032	0.032
Lag 15	0.078	0.000	0.001	0.006	-0.042	0.003
	0.016***	0.003	0.002	0.027	0.032	0.033
Lag 16	0.076	0.000	0.001	0.008	-0.038	-0.009
	0.016***	0.003	0.002	0.026	0.031	0.033
Lag 17	0.074	0.000	0.001	0.011	-0.030	-0.016
	0.015***	0.003	0.002	0.026	0.030	0.033
Lag 18	0.071	-0.001	0.001	0.010	-0.029	-0.015
	0.016***	0.004	0.002	0.026	0.030	0.033
Lag 19	0.070	-0.001	0.001	0.009	-0.028	0.001
	0.016***	0.004	0.002	0.027	0.031	0.033
Lag 20	0.065	-0.001	0.001	0.010	-0.040	0.009
	0.016***	0.004	0.002	0.026	0.032	0.033
Lag 21	0.062	-0.001	0.001	0.013	-0.063	0.007
	0.016***	0.003	0.002	0.026	0.033**	0.032
Lag 22	0.059	-0.001	0.001	0.013	-0.070	0.000
	0.016***	0.003	0.002	0.026	0.033***	0.033
Lag 23	0.056	0.000	0.001	0.014	-0.056	0.006
	0.017***	0.003	0.002	0.026	0.033*	0.033
Lag 24	0.048	-0.001	0.001	0.012	-0.034	0.019
	0.017***	0.003	0.002	0.027	0.032	0.033

*Independent variable is the crisis index defined in Section 2. Standard errors in small font, robust estimates using countries as clusters *, **, and *** indicate significance at the 10%, 5%, 1% level respectively.*

The outcome is very clear: some variables have a very short-term impact, such as the short-term debt to reserve ratio, some have both a very short-term and a longer term impact (such as the contagion variable), some have a short- to medium-term impact (such as the lending boom), some always seem to have an impact (such as the exchange rate), while for growth and the current account, no impact can be detected. The results make sense intuitively. The short-term debt variable has a short-run impact almost by definition (short-term debt is defined as debt below six month maturity), while an exchange rate over-appreciation can develop over several years before translating into a full-fledged crisis. One implication is that a “signal” sent by a high short-term debt to reserve ratio may indicate that a crisis is imminent, leaving very little time for policy makers to act. By contrast, an exchange rate over-appreciation may not signal a looming crisis and can be addressed by longer-term measures.

Chart 1: Impact of selected crisis indicators at different lags (in months), point estimate and confidence interval.



This section has demonstrated that different specifications can yield diverging conclusions. When fixed effects are not taken into account, some variables do not enter the model significantly, whereas they do when country effects are included. The current account deficit is one example. This effect probably arises because some countries are outliers: for instance, Singapore always runs a very large current account surplus (perhaps linked to its size and geographical situation), and experienced one crisis in 1997. If the number and importance of such outliers are large enough, they may drive the results.

Using a dynamic panel also has important consequences that can best be seen comparing Table 2 and Table 4 (none of the results included in these two tables use fixed effects to isolate the effect of using a dynamic panel). The "lending boom" is an example of a variable that is significant in a static model but not in a dynamic framework. As mentioned in Section 2 the "lending boom" variable is an indicator with a short-run effect, so including even as few as six months of the lagged dependent variable could partly pick up the effect of this variable.[28] In the case of the contagion variable, the fact that the coefficient of the lagged dependent variable is significant at lag 5 and 6 may explain why the contagion variable is not significant in the dynamic specification (given that results presented in Table 6 show that the contagion variable is significant precisely at lags 5 and 6).

Since part of the motivation of most papers in the literature is to actually predict crises and not just understand the sign and significance of a variable, a word has to be said of the predictive power of the model. In a nutshell, the model does not fare well compared to Bussière and Fratzscher (2002), and to some of the other models therein reviewed. This is due to the fact that the model is designed to make a statement about the precise timing of the crisis, which is very difficult. In the dynamic model lags 5 and 6 were found significant: it means that for many countries a crisis follows another in a six month interval. Yet, this empirical regularity is not matched by all countries, for which the model mistakenly predicts a rise in the probability of a crisis 5 and 6 months after a crisis has burst out. To bypass this problem we need to adapt the model, which is the purpose of section 5.

5. Results based on a transformed crisis index: extending the prediction window

The results presented in the last section conveyed important messages. However, in terms of prediction the model fared relatively poorly. This is because the model attempted to achieve something that may simply be infeasible: predict the timing of a crisis. Perhaps a different way to formulate the question would allow to still retrieve some useful information on when a crisis may happen. This is for instance the approach chosen by Fuertes and Kalotychou (2004), who also review the literature on the subject.

If, instead of trying to predict which month a crisis may happen, one is willing to extend the window to one whole year (the next 12 months), then the left-hand side variable can be transformed as follows:[29]

$$FY_i^t = \begin{cases} 1 \; if \; \exists \, k = 1,...12 \; s.t. \; CI_i^{t+k} = 1 \\ 0 \; otherwise \end{cases}$$

and regress this forward crisis index on the contemporaneous fundamentals X_i^t. Using this definition of the variables we are sure that what appears on the right-hand side does not appear

[28] It also suggests that results for the effect of the lending boom variable are simply not very robust, as noticed already in a cross-section context (Bussière and Mulder, 1999).

[29] This definition corresponds to the periods where the crisis index is equal to one in Bussière and Fratzscher (2006).

simultaneously on the left-hand side: the statement the model makes is that the magnitude of the exchange rate over-appreciation *now* (to take just one example) can determine the likelihood of a strong depreciation *in any of the successive 12 months*. The question the model is tackling is then: are fundamentals in the 12 months preceding a crisis different from what they are the rest of the time? Results broadly confirm the results from Section 4 regarding the significance of the main variables (Table 7), the main difference being that the growth variable now has a significant coefficient.

What is a dynamic panel in this setting? Clearly lagging the crisis index 1, 2 or 6 months would not bring any interesting information since the independent variable would by construction coincide with the lagged dependent variable during 11, 10 or 6 months respectively. The solution is to lag the dependent variable 12 months. This method also allows one to extend the time during which a crisis has an effect to one year instead of just six months as in the preceding section. It could be extended to longer timeframe in further research.

Results in Table 7 and 8 are qualitatively similar as those of Tables 2-5, the same variables being significant in both cases. However, goodness of fit is much better (see also Chart Appendix). It is noteworthy that with the transformed index, the dynamic model shows that the lagged dependent variable is not significant (implying that beyond the six month interval identified in the previous version, there is not much of an effect for the lagged dependent variable). Overall, this model would have predicted most crises, such as the 1995 and 1998 crises in Brazil, the 1998 crisis in Chile, the 1994 Tequila crisis in Mexico, the 1998 Russian crisis, the 1998 Asian crisis for all countries represented here, as well as the crises that hit Argentina and Turkey in 2001 (assuming of course timely publication of the indicators). It would however have missed the 1995 crisis in Argentina and sent a false alarm for Hungary in 1999.

Comparing the two panels (left and right) of Table 7 provides the same insight as when comparing the results of Table 2 and 3: with fixed effects, the coefficient of the current account becomes significant and the coefficient of short-term debt is roughly twice as large. Meanwhile, comparing the two panels of Table 8 yields very similar conclusions to each other.[30] Similar to the results presented in Section 4, the coefficient of the lending boom variable becomes insignificant in the dynamic model specification, most likely for the same reasons as explained at the end of Section 4.

[30] Bussiere and Fratzscher (2006), where the dependent variable is also a transformed index similar to the one used in Table 7 and Table 8, also concludes that fixed effects do not have a significant impact on the results. This contrasts with the results presented in Table 2-5 (with the untransformed index).

Table 7: Estimation results using the transformed crisis index, static model, with and without fixed effects (country dummies).

	No fixed effects				With Fixed effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exch. Rate, dev. from trend	0.099 0.026***	0.101 0.024	0.104 0.02***	0.092 0.023***	0.100 0.009***	0.119 0.010***	0.131 0.011***	0.106 0.009***
Lending boom	0.007 0.003***	0.007 0.003	0.007 0.003***	0.007 0.003**	0.006 0.001***	0.006 0.001***	0.006 0.001***	0.006 0.001***
Short-term debt / Reserves	0.004 0.003*	-	-	0.003 0.003	0.009 0.002***	-	-	0.012 0.002***
Total debt / Reserves (locat. concept)	-	0.002 0.001	-	-	-	0.008 0.001***	-	-
Total debt / Reserves (consolidated concept)	-	-	0.005 0.001***	-	-	-	0.013 0.001***	-
Current account surplus	-0.014 0.03	-0.009 0.025	-0.012 0.026	-	-0.083 0.025***	-0.071 0.025***	-0.061 0.025***	-
Government surplus	-	-	-	0.061 0.018	-	-	-	0.243 0.054***
Financial contagion	0.069 0.018***	0.070 0.018***	0.071 0.02	0.063 0.018***	0.074 0.011**	0.084 0.012***	0.077 0.011***/	0.071 0.011***
Growth rate	-0.051 0.028*	-0.049 0.027*	-0.04 0.028	-0.063 0.02***	-0.035 0.017***	-0.038 0.017***	-0.026 0.018***	-0.059 0.018***
Constant	-2.015 0.381	-1.976 0.381***	-2.489 0.431	-1.761 0.366	-2.623 0.367***	-2.867 0.349***	-4.640 0.475***	-2.268 0.378***
# obs	1741	1741	1741	1717	1417	1417	1417	1393
Pseudo R^2	0.186	0.185	0.209	0.172	0.245	0.269	0.287	0.240
Log likelihood	-752.04	-752.65	-730.45	-750.02	-620.19	-600.17	-585.75	-611.78

Standard errors for the results using no fixed effects are robust corrections using countries as clusters. Fixed effects refer to country dummies (not reported here for space reason).

Table 8: Estimation results using the transformed crisis index, dynamic model, with and without fixed effects (country dummies).

	No fixed effects				With Fixed effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lagged dependent variable	0.481 0.490	0.478 0.494	0.391 0.536	0.372 0.459	0.046 0.226	0.020 0.229	0.020 0.232	-0.232 0.225
Exch. Rate, dev. from trend	0.105 0.029***	0.106 0.028***	0.109 0.027***	0.099 0.027***	0.103 0.010***	0.123 0.011***	0.134 0.011***	0.107 0.010***
Lending boom	0.003 0.005	0.004 0.005	0.004 0.005	0.004 0.485	0.002 0.002	0.002 0.002	0.001 0.002	0.002 0.002
Short-term debt / Reserves	0.004 0.003*	-		0.003 0.003	0.009 0.002***		-	0.012 0.002***
Total debt / Reserves (locat. concept)	-	0.002 0.001	-	-	-	0.008 0.001***	-	-
Total debt / Reserves (consolidated concept)	-	-	0.004 0.005	-	-	-	0.013 0.001***	-
Current account surplus	-0.022 0.027	-0.018 0.027	-0.021 0.028	-	-0.092 0.026	-0.081 0.025***	-0.070 0.026***	-
Government surplus	-	-	-	0.049 0.056	-	-	-	0.273 0.056
Financial contagion	0.066 0.019	0.067 0.019***	0.068 0.019	0.061 0.019***	0.075 0.011***	0.086 0.012***	0.079 0.012***	0.074 0.011
Growth rate	-0.038 0.030	-0.036 0.030	-0.032 0.030	-0.052 0.031*	-0.036 0.019**	-0.039 0.018***	-0.029 0.019***	-0.072 0.019
Constant	-2.102 0.437***	-2.060 0.438***	-2.535 0.456	-1.840 0.407	-2.619 0.369***	-2.878 0.353***	-4.722 0.482***	-2.191 0.382
# obs	1721	1721	1721	1697	1409	1409	1409	1385
Pseudo R^2	0.183	0.182	0.205	0.167	0.243	0.269	0.288	0.239
Log likelihood	-742.66	-743.43	-722.47	-742.69	-614.19	-592.92	-577.89	-604.73

6 Conclusions

This paper has presented, for the first time in the context of financial crises in emerging market, a set of discrete choice models with a dynamic specification and a specification where the explanatory variables are tested at different lags. It has also discussed the issue of potentially spurious state dependence and the practice of using a dependent variable defined as a forward index, equal to one during a time window.

Several conclusions can arise from this analysis. First, the early indicators used to detect crises ahead of time seem to perform relatively well if the purpose is to predict crises in a given time window; however, they are much less efficient in predicting the exact starting date of the crisis. Overall, the main economic variables that are found to predict crises are the ratio of short-term debt to international reserves, the growth rate of credit to the private sector, the over-appreciation of the nominal effective exchange rate (with respect to trend) and contagion from other countries. Second, the dynamics of currency crises appear more clearly with the models presented in Section 4 (with the untransformed index): often, crises happen in the same country at few months interval, typically 5 to 6 months. This empirical regularity would suggest that attention should not vanish after a crisis has happened as another one may be pending. Third, different indicators signal crises at different lags, some being very short-term (e.g. the short-term debt to reserves ratio or financial contagion), others with a longer lag (e.g. the lending boom variable or the degree of exchange rate over-appreciation). This suggests that when a country faces liquidity problems or financial contagion from crises in other emerging markets, policy reaction must be particularly quick (a few months at most). Interestingly, in the case of contagion, one can observe a switch in the sign of the variable in the long run. This could suggest that contagion is sometimes positive (exchange market pressure in a given country may actually decrease if a crisis happens in another country). This may arise if investors relocate their investments across emerging markets (e.g., investors may have invested more in Asia after the 1995 Tequila crisis, which may have temporarily decreased exchange market pressure in Asian EMEs). This line of analysis may be more extensively conducted in future research. Generally, future extensions of the present framework may more systematically select the lag structure of the explanatory variables. Future research may also use new econometric methods to disentangle true from spurious state dependence.

References

Baltagi, Badi, 2001, *Econometric Analysis of Panel Data*, Second Edition, John Wiley & Sons, Ltd.

Berg, A. and C. Patillo, 1999, “Predicting Currency Crises: The Indicators approach and alternative”, *Journal of International Money and Finance*, **18**, 561-586.

Berg, Andrew, Eduardo Borensztein, and Catherine Pattillo, “Assessing Early Warning Systems: How Have They Worked in Practice?”, *IMF Working Paper* WP/04/52.

Bernanke, Ben S., 2005, “The Global Saving Glut and the U.S. Current Account Deficit”, Homer Jones Lecture, St. Louis, Missouri, April 14, 2005.

Bussiere, Matthieu and Christian Mulder, 1999a, “Political Instability and Economic Vulnerability”, with Christian Mulder, *International Journal of Finance and Economics;* October 2000, **5**(4), p. 309-330 and IMF Working Paper 1999/46.

Bussiere, Matthieu and Christian Mulder, 1999b, “External Vulnerability in Emerging Market Economies: How High Liquidity Can Offset Weak Fundamentals and the Effects of Contagion”, *IMF Working Paper*, WP/99/88.

Bussiere, Matthieu and Marcel Fratzscher, 2006, “Towards a New Early Warning System of Financial Crises”, *Journal of International Money and Finance*, October 2006.

Bussiere, Matthieu, Marcel Fratzscher and Winfried koeniger, 2006, “Uncertainty and Debt Maturity in Emerging Markets”, *Berkeley Electronic Journals, Topics in Macroeconomics*, **6**(1), Article 5. http://www.bepress.com/bejm/topics/vol6/iss1/art5.

Calvo, Guillermo A., 1998, “Capital Flows and Capital-Market Crises”, *Journal of Applied Economics;* **1**(1), November 1998, p. 35-54.

Calvo, Guillermo A., and Enrique Mendoza, 2000, Rational Contagion and the Globalization of Securities Markets. *Journal of International Economics;* **51**, p. 79-113.

Calvo, Guillermo and Ernesto Talvi, 2005, “Sudden Stop, Financial Factors and Economic Collapse in Latin America: Learning from Argentina and Chile”, *NBER Working Paper* 11153, Cambridge MA.

Calvo, Guillermo, Alejandro Izquierdo and Luis F. Mejia, 2004, “On the Empirics of Sudden Stops: the Relevance of Balance Sheet Effects”, *NBER Working Paper* 10520, Cambridge MA.

Chamberlain G., 1980, “Analysis of Covariance with Qualitative Data”, *Review of Economic Studies;* **47**, p. 225-238.

Chamberlain, G., 1985, “Heterogeneity, omitted variable bias and duration dependence”, in *Longitudinal Analysis of Labor Market Data* (Cambridge University Press, Cambridge), p. 3-38, ed. by Heckman, J. and Singer, B.

Dornbusch, Rudiger, I. Goldfajn and R. Valdès, 1995, “Currency Crises and Collapses”, *Brookings Papers on Economic Activity;* **2**, p. 219-293.

Eichengreen, Barry, Andrew Rose and Charles Wyplosz, 1995, “Exchange Market Mayhem: The Antecedents and Aftermaths of Speculative Attacks”; *Economic Policy*, **21**, p. 249-312.

Eichengreen, Barry, Andrew Rose and Charles Wyplosz, 1996, “Contagious Currency. Crises”, *Scandinavian Economic Review* **98**(4), 1996 p.463-84.

Feldstein, Martin, 1999, “Self-Protection for Emerging Market Economies”, *NBER Working Paper*, No. 6907, Cambridge MA.

Flood, Robert P., Nancy P. Marion. (1998). “Perspectives on the Recent Currency Crises Literature”, NBER Working Paper No. 6380, Cambridge MA.

Frankel, Jeffrey and Andrew Rose, 1996, “Currency Crashes in emerging Markets: an Empirical Treatment”, *Journal of International Economics;* **41**, p. 351-366.

Fratzscher, Marcel, 1998, “Why Are Currency Crises Contagious? A Comparison of the Latin American Crisis of 1994-1995 and the Asian Crisis of 1997-1998”, *Weltwirtschaftliches Archiv/Review of World Economics*; **134**(4), 1998, p. 664-91.

Fratzscher, Marcel, 2003, “On Currency Crises and Contagion”, *International Journal of Finance and Economics;* **8**(2)**,** April 2003, p. 109-30.

Fuertes, Ana-Maria and Elena Kalotychou, 2004, “Modeling Sovereign Debt Crises Using Panels”, *Centre for Economic Analysis, Working Paper WP-CEA-11-2004*, December 2004.

Georgievska, A., L. Georgievska, A. Stojanovic and N. Todorovic, 2006, “Modelling Sovereign Debt Rescheduling Probabilities in Emerging Markets”, *Cass Business School Working Paper*.

Girton, L. and D. Roper, 1977, “A Monetary Model of Exchange Market Pressure Applied to Postwar Canadian Experience”, *American Economic Review* 67, 537-548.

Glick, Reuven, and Andrew Rose, 1999, “Contagion and Trade: Why are Currency Crises Regional?”, *Journal of International Money and Finance*; **18**(4), p. 603-618.

Heckman, J. J., 1981a, “Statistical models for discrete panel data”, in C. F. Manski and D. McFadden, eds., *Structural Analysis of Discrete Data with Econometric Applications* (MIT Press, Cambridge), p. 114-178.

Heckman, J. J., 1981b, “The incidental parameters problem and the problem of initial conditions in estimating a discrete time-discrete data stochastic process”, in C. F. Manski and D. McFadden, eds., *Structural Analysis of Discrete Data with Econometric Applications* (MIT Press, Cambridge), p. 179-195.

Heckman, J. J., 1981c, “Heterogeneity and State Dependence”, in S. Rosen, ed., *Studies in Labor Markets* (Chicago University Press, Chicago), p. 91-139.

Honoré, Bo and Ekaterini Kyriazidou, 2000, “Panel Data Discrete Choice Models with Lagged Dependent Variables”, *Econometrica*; **68**(4), July 2000, p. 839-74.

Eichengreen, Barry, 2000, “The EMS Crisis in Retrospect”, *NBER Working Paper* No. 8035.

Kaiser, Ulrich and Hans Christian Kongsted, 2004, “True versus Spurious State Dependence in Firm Performance: The Case of West German Exports”, *ZEW Discussion Paper* No. 04-81.

Kamin, Steven, 1999, “The Current International Financial Crisis: How Much Is New ?”, *Journal of International Money and Finance*; **18**(4), August 1999, p. 501-514.

Kamin, Steven and Sergio Schmukler, 1999, “What Triggers Market Jitters: A Chronicle of the Asian Crisis”, Board of Governors of the Federal Reserve System, *International Finance Discussion Papers Number 634*, April 1999.

Kamin, Steven and Oliver Babson, 1999, “The Contribution of Domestic and External Factors to Latin American Devaluation Crises: An Early Warning Systems Approach”, Board of Governors of the Federal Reserve System, *International Finance Discussion Papers Number 645*, September 1999.

Kaminsky, Graciela L. and Carmen M. Reinhart, 1998a, “Financial Crises in Asia and Latin America: Then and Now”, *American Economic Review*; **88**(2), May 1998, p. 444-48.

Kaminsky Graciela L., Saul Lizondo and Carmen M. Reinhart, 1998b, “Leading Indicators of Currency Crises,” IMF *Staff Papers*, **45**(1), p. 1-48.

Kaminsky, Graciela L. and Carmen M. Reinhart, 1999, “The Twin Crises: The Causes of Banking and Balance-of-Payments Problems”, *American Economic Review*; **89**(3), June 1999, p. 473-500.

Kaminsky, Graciela L. and Carmen M. Reinhart, 2000, “On Crises, Contagion, and Confusion”; *Journal of International Economics*; **51**(1), June 2000, p. 145-168.

Krugman, Paul, 1979, “A Model of Balance-of-Payments crises”, *Journal of Money, Credit and Banking*, **11** (August), p. 311-325.

Krugman, Paul, 1998, “What Happened to Asia?,” Unpublished Manuscript, MIT, 1998.

Maddala, G.S., *Limited-dependent and Qualitative Variables in Econometrics*, Econometric Society Monographs, Cambridge University Press, 1989.

Milesi-Ferretti, Gian-Maria and Assaf Razin, 1996, “Persistent Current Account Deficits: A Warning Signal ?”, *International Journal of Finance and Economics*; **1**, p. 161-181.

Milesi-Ferretti, Gian-Maria and Assaf Razin, 1998, “Current Account Reversals and Currency Crises: Empirical Regularities”, *IMF Working Paper 98/89*, also “Sharp Reductions in Current Account Deficits: an Empirical Analysis”, *European Economic Review;* **42**(3-5), p. 897-908.

Obstfeld, Maury, 1994, "The logic of currency crises", *Cahiers Economiques et Monetaires,* **43**, p. 189-213.

Peltonen, Tuomas, 2006, “Are currency crises predictable ? A Test”, *ECB Working Paper* No. 571, January 2006.

Pesaran, Hashem M. and Andreas Pick, 2006, “Econometric issues in the analysis of contagion”, forthcoming *Journal of Economic Dynamic and Control*.

Sachs, Jeffrey, Aaron Tornell and Andres Velasco, 1996, “The Mexican Peso Crisis: Sudden Death Or Death Foretold ?”, *Journal of International Economics;* **41,** p. 265-283.

Sachs, Jeffrey, Aaron Tornell and Andres Velasco, 1996, “Financial Crises in Emerging Markets: The Lessons from 1995”, *Brookings Papers on Economic Activity*; **10**(1), 1996: 147-98.

Tornell, Aaron, 1999, “Common Fundamentals in the Tequila and Asian Crises”, *NBER Working Paper*, 7139, May 1999.

Wooldridge, Jeffrey M., 2001, *Econometric Analysis of Cross Section and Panel Data*, MIT Press.

Zanello, Alessandro and Dominique Desruelle, 1997, “A Primer on the IMF's Information Notice System”, *IMF Working Paper*, WP 97/71.

Charts Appendix

Exchange Rate Indices and Crisis Definition

Chart: Argentina

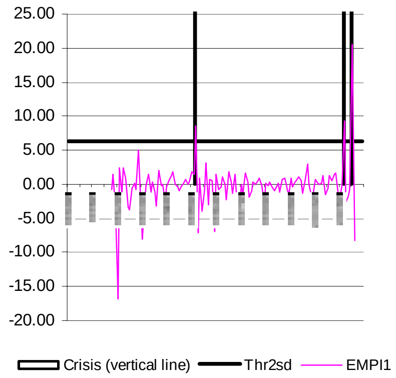


Chart: Brazil

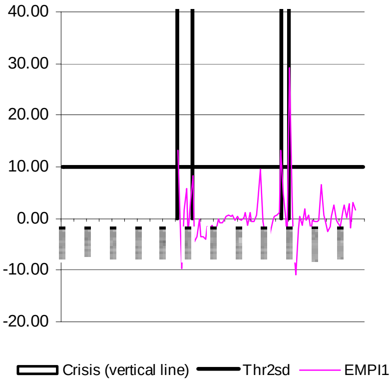


Chart: Mexico

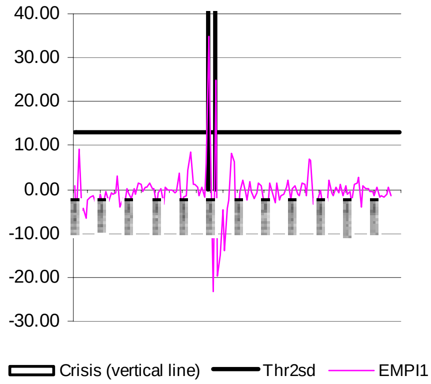


Chart: Hong Kong

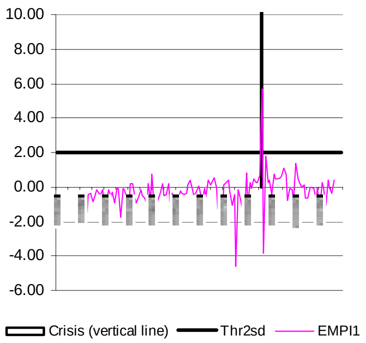
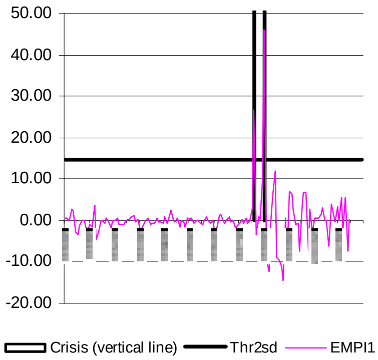


Chart: Indonesia



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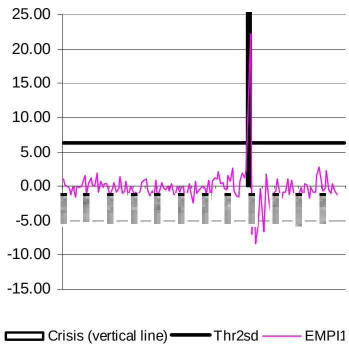

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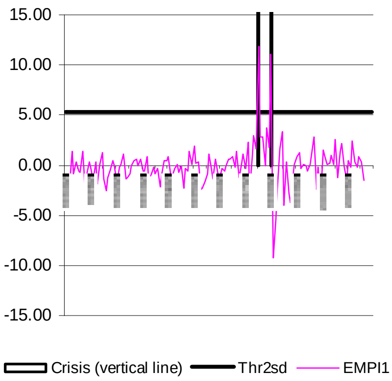

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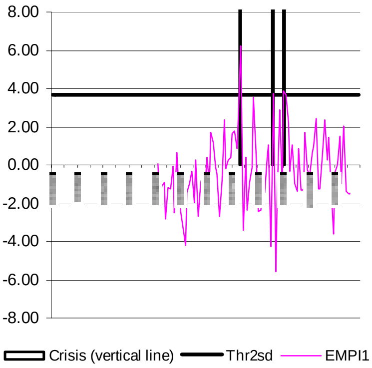

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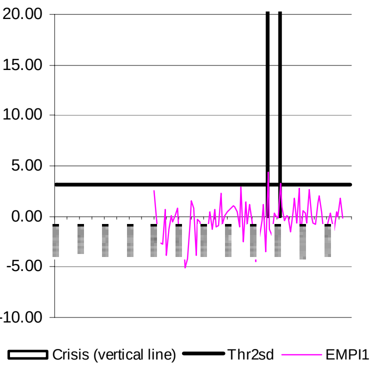

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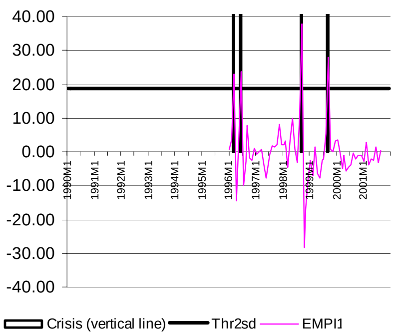
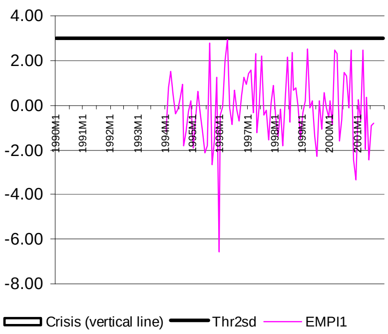


Chart: Hungary



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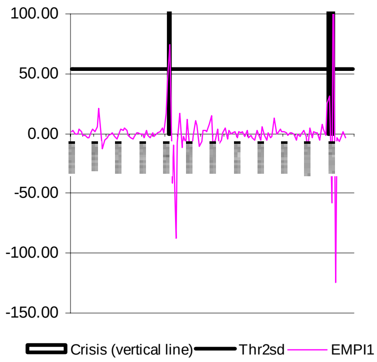
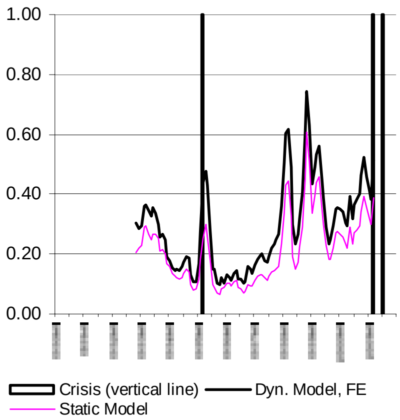


Crisis Probability Computed with Different models

Chart: Argentina



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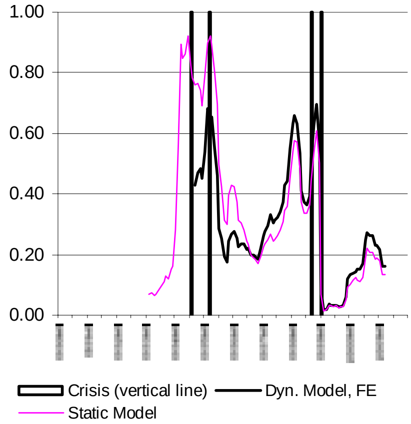


Chart: Chile

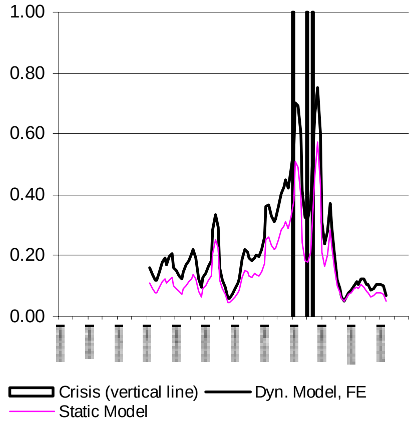


Chart: Mexico

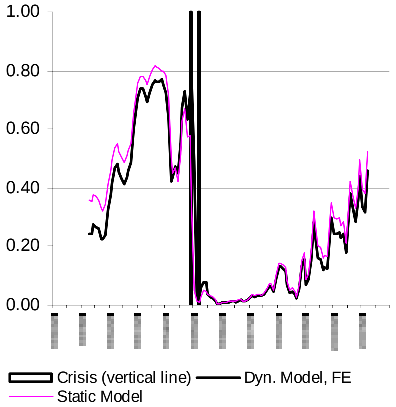


Chart: Indonesia

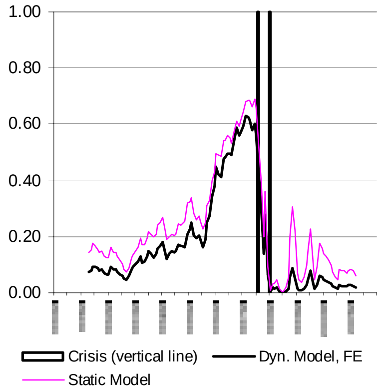


Chart: Malaysia

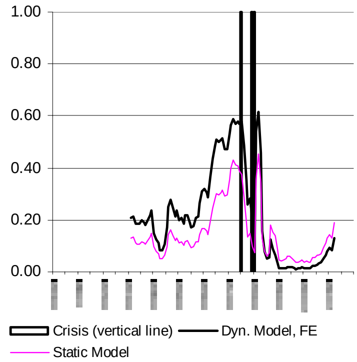


Chart: Thailand

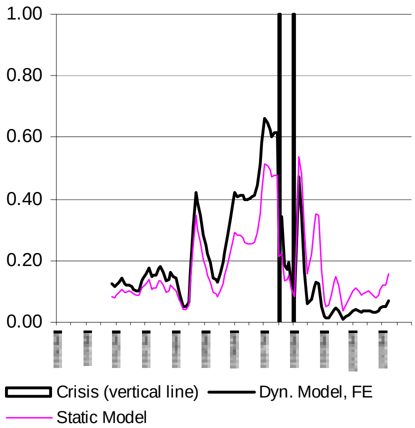


Chart: Czech Rep.

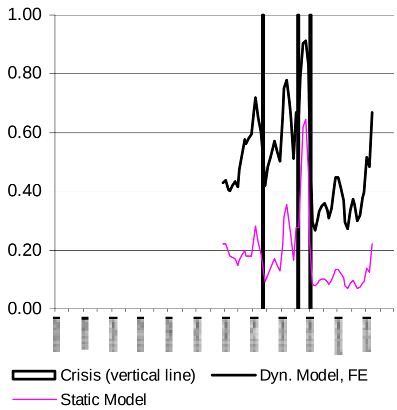


Chart: Poland

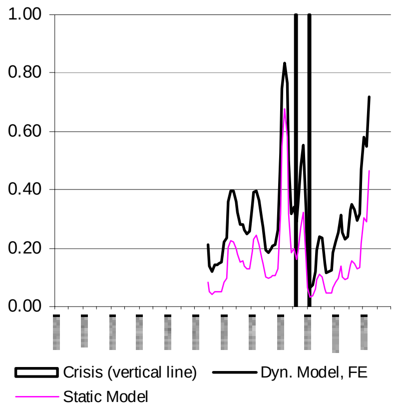


Chart: Turkey

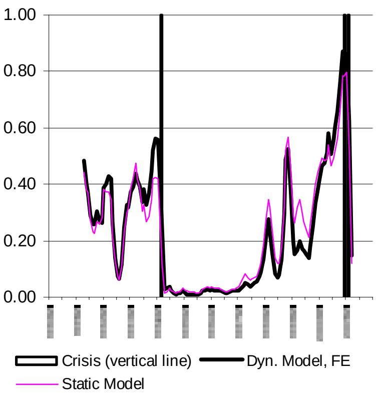


Chart: Russia

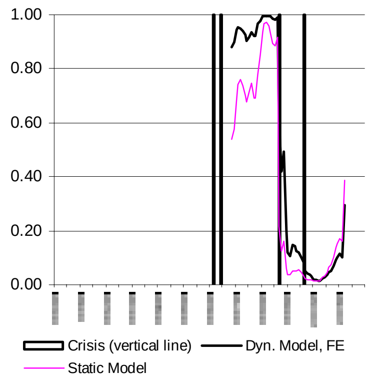
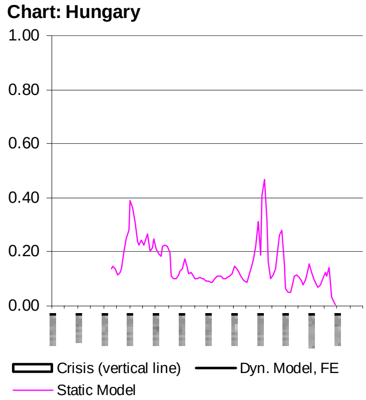


Chart: Hungary



Country and Data Appendix

Table 9: Country List

Latin America	Asia	Eastern Europe
Argentina	China	Czech Republic
Brazil	Hong Kong	Estonia
Chile	India	Hungary
Colombia	Indonesia	Latvia
Ecuador	Korea	Lithuania
Mexico	Malaysia	Poland
Peru	Philippines	Russia
Venezuela	Singapore	Slovak Republic
	Thailand	Slovenia
		Turkey

Data sources. Five different sources have been used for the macro and financial variables: the IMF International Financial Statistics (IFS), the IMF-World Bank-OECD-BIS joint table for the debt statistics available on-line (BIS), the World Market Monitor from DRI-WEFA (WMM) / Global Insight, J.P. Morgan (JPM), and Datastream (DS) for the market indices. Data relative to Taiwan were all taken from WMM; original data come from Central Bank of China and Directorate General Of Budget. Data are retrieved on a monthly (M), quarterly (Q), semi-annual (SA) or yearly (Y) basis and linearly interpolated when necessary.

The computation of the **dependent variable** was done in two steps:
<u>Step 1</u> Computation of the (continuous) Exchange Market Pressure Index
Exchange market pressure indices (EMPI) represent a synthetic measure of the pressure against a given currency. The EMPI is defined as a weighted average of three components:

$$EMP_t^i = \omega_{RER}\left(\frac{RER_t^i - RER_{t-1}^i}{RER_{t-1}^i}\right) + \omega_r(r_t^i - r_{t-1}^i) - \omega_{res}\left(\frac{res_t^i - res_{t-1}^i}{res_{t-1}^i}\right)$$

Where:
- RER is the real effective exchange rate (coming mostly from IFS line rec and from JP-Morgan –the exchange rate is measured so that an increase is a depreciation;
- r is the real interest rate –chosen as a short-term rate (e.g. IFS line 60.$ and WMM sources);
- res is the level of international reserves.

The weights sum up to 1 and correspond to the average precision of the three series (around 0.6, 0.2 and 0.2 respectively).

<u>Step 2</u> Transformation of the EMPI into a Binary Variable
The continuous EMP index is transformed into a discrete variable using a cut-off point. The threshold is equal to the country specific mean of the EMP index, plus two standard deviations:

$$CI_t^i = \begin{cases} 1 & if \quad EMP_t^i > \overline{EMP^i} + 2\ SD(EMP^i) \\ 0 & otherwise \end{cases}$$

The independent variables were computed as follows:

Debt ratios. The appropriate way to scale short-term debt is to use the so-called Greenspan-Guidotti ratio:

$$STDR_t^i = \frac{STD_t^i}{\mathrm{Re}\, s_t^i} * 100$$

A rise in this ratio can come from either a rise in debt or a drop in reserves, which is exactly what the "Greenspan-Guidotti rule" states: reserves should cover entirely the amount of debt that can be sold short-term by investors in case of an attack. The long-term debt ratio was computed in the same fashion. The BIS database on debt statistics includes bank loans (BIS Line A), Brady Bonds (Line C), liabilities within one year (Line G), total liabilities, locational concept (Line J), total liabilities, consolidated concept (Line K). Reserves come from IFS line 11.d (total reserves minus gold).

Current account. The raw data come from IFS line 78ald, as well as Global Insight. The GDP was transformed into a monthly series using linear interpolation techniques; using industrial production as a complement yielded similar results. The current account was downloaded at a monthly frequency for some countries; when it was only available at a quarterly frequency I used linear interpolation techniques. Using information from the tade balance yielded very similar results.

Government surplus. The government budget balance is referred to in the Tables as "government surplus" (in some papers, it actually refers to the government deficit; here, a positive sign does indicate a surplus). The raw data come from IFS line 80 and from Global Insight. It therefore represents a non-cyclically adjusted balance, also including debt repayment. The fact that it is not cyclically adjusted is controlled for by using also GDP growth in the specifications.

Over-valuation relative to trend. This paper uses the International monetary Fund real effective exchange rate, which is a comprehensive measure including competition in third markets; it was complemented for some countries by the JP Morgan index. The trend was defined as a simple linear trend.

$$REERDEV_t^i = \frac{\left(REER_t^i - TREND_t^i\right)}{TREND_t^i} * 100$$

The trend is a simple linear trend as is usual in the literature. It is computed over the whole sample to simplify and above all because of the nature of emerging markets, for which data series are available since the early 1990's only. In Bussiere and Fratzscher (2006), a change in the exchange rate over the past 24 months is used, with similar results (although a fall in the predictive power of the model can be noted, the model still outperforms alternative models published in international journals).

Lending boom. As the exact number of non-performing or bad loans in the economy is not directly observable for obvious under-reporting reasons, the literature has searched proxies. The so-called "lending boom", that measures the increase of the credit to the private sector (CPS) over a 2 or 3 year period, can be useful in this respect (see Tornell, 1999). Here the measure is transformed as a deviation from a one year average with a two year lag to avoid base effects:

$$LB_t^i = \left(\frac{CPS_t^i}{GDP_t^i} - \overline{\frac{CPS_{t-24}^i}{GDP_{t-24}^i}}\right) * 100$$

Where:

$$\overline{\frac{CPS^{i}_{t-24}}{GDP^{i}_{t-24}}} = \frac{1}{12}\sum_{k=0}^{11}\frac{CPS^{i}_{t-24-k}}{GDP^{i}_{t-24-k}} * 100$$

The credit to the private sector is measured as a percentage of the GDP to account for the size of the economy; the raw data come from IFS line 32b.

Growth. The growth rate of real GDP is simply computed as below (monthly series were interpolated from quarterly data). The raw data come from IFS line 99b and from Global Insight.

$$GROWTH^{i}_{T} = \frac{GDP^{i}_{t} - GDP^{i}_{t-12}}{GDP^{i}_{t-12}} * 100$$

Contagion. The contagion variables are defined in Bussiere and Fratzscher (2006). Contagion across countries can take different channels, among others financial and trade linkages. As the former are generally found significant and not the latter (see Bussière and Fratzscher, 2006), the present paper focuses only on financial contagion. The degree of financial interdependence between country i and country j is proxied by the cross-country correlation of equity market returns in country i and in country j [31] (discounted from the impact of other fundamentals, see above reference for further details):

$$FINCONT_{ij} = correl\ (\mu_i, \mu_j)$$

Next, the measures of real or financial interdependence for each country is interacted with the crisis index: for each country i and its N-1 partners j:

$$CONTAGION^{t}_{i} = \sum_{j=1}^{N-1} EMPI^{t}_{j} * FINCONT^{t}_{ij}$$

Market indices. The market value of key stock indices (here, Datastream indices) was transformed into a 12 month percent change. Three indices were used: a broad market index, and two sub-indices on banks and financial institutions.

[31] This correlation is measured in tranquil periods, otherwise there would be of course an endogeneity problem.

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