

# In Defense of Early Warning Signals<sup>1</sup>

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## Abstract

The 2008 financial crisis has rekindled interest in the issue of early warning signals (EWS) of financial distress. It has also triggered renewed interest in the literature on currency crises, with many countries, especially among emerging market economies and new EU Member States, experiencing severe exchange market pressure. While several policy institutions are in the process of developing new early warning systems, there is a lot of skepticism on the ability to predict currency crises or, more generally, any type of financial crises. This skepticism stems from the poor out-of-sample performance of leading models, but also from a more fundamental objection, according to which it is by definition impossible to predict crises – what we refer to as an “impossibility theorem”. Moreover, others challenge such systems by saying that they contribute to the phenomenon they are supposed to fight (the self-fulfilling prophecies view). The objective of this paper is to challenge this skeptical view. To this aim, we discuss the general conditions under which the “impossibility theorem” may fail and self-fulfilling prophecies can be avoided, stemming e.g. from political economy arguments. We illustrate the ability of a simple currency crisis model to provide useful information on economic vulnerabilities by testing its out-of-sample performance in a panel of emerging market and new EU economies, applied to the period following the collapse of Lehman Brothers.

**Key words:** Exchange rates, currency crises, financial crises, emerging market economies, New EU Member Countries, European Systemic Risk Board.

**JEL:** B40, C52, C53, F31, G01.

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## 1 Introduction

The ongoing financial crisis, which started in 2007 and intensified in September 2008, has rekindled interest in early warning signals of financial distress. Indeed, while it would be unrealistic to prevent any sort of output or asset price fluctuations, the social cost of the crisis appears so large that there is growing consensus on the necessity to anticipate such events and avoid their occurrence, looking forward. The financial crisis has also brought back on the policy agenda the issue of currency crises, with many emerging market economies and new EU Member States experiencing severe exchange market pressures. Among the latter, Hungary was particularly affected: the Hungarian Forint started to depreciate rapidly in the wake of the failure of Lehman Brothers (the depreciation against the US dollar reached nearly 60% in the first quarter of 2009, compared to its pre-crisis level). Hungary also lost 10% of its international reserves between September and October 2008). This pressure actually led Hungary to come to an agreement with the IMF and the European Union in October 2008. Hungary was unfortunately not the only EU country to experience such severe foreign exchange pressure: over the same time periods, the Polish Zloty depreciated by 73% and Poland lost 13% of its reserves.

Against this background, several policy institutions are looking again into early warning signals of currency and financial crises and the relevant literature such as Frankel and Rose (1996), Kaminsky and Reinhart (1999), Demirguc-Kunt and Detragiache (1998), Bussière and Fratzscher (2006), Berg and Pattillo (1999b), or Bussière and Mulder (1999). While these papers rely on different methods – which the paper will come back to– and tackle different types of crises, what they have in common is that they all try to explain the occurrence of crises with a set of appropriately chosen variables (the “indicators”, or “early warning signals”), taken at a given lag. Once estimated, the models can be used to predict future crises by updating the explanatory variables and computing the (forward looking) crisis index.

However, just as policy institutions are again developing such early warning systems, the economic profession as a whole tends to show marked skepticism towards the efficiency of such models. In the case of currency crises, part of the skepticism comes from the result presented in Meese and Rogoff (1983), showing that it is difficult to beat a naïve exchange rate model (the random walk). As this result has proved very strong and difficult to overturn, with very few exceptions, the ability to predict currency crises –a particular form of exchange rate changes— seems very uncertain.<sup>2</sup> In addition, the influential paper by Berg and Pattillo (1999a) has cast doubt on the out-of-sample performance of prominent currency crisis models. More recently, Rose and Spiegel (2009) have analyzed the causes and consequences of the 2008 crisis for a cross-section of 107 countries (including several new EU member states) and found that their explanatory variables fail to account for the occurrence of crises in their sample, which, according to them, is a valid reason to be skeptical of early warning signals.<sup>3</sup> Part of the reason behind this result, however, may be that their crisis index is very composite and encompasses very different events (real GDP, the stock market, country credit ratings and the

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<sup>2</sup> Add footnote here to reflect comment by Frankel on Meese-Rogoff (results might change whether one looks at first differences or the level of the exchange rate).

<sup>3</sup> To quote their main findings: “Despite the fact that we use a wide number of possible causes in a flexible statistical framework, we are unable to link most of the commonly-cited causes of the crisis to its incidence across countries. This negative finding in the cross-section makes us skeptical of the accuracy of “early warning” systems of potential crises, which must also predict their timing.”.

exchange rate). By contrast, we argue in the paper that focusing on specific events (in our case using an exchange market pressure index) yields very good results, perhaps because it is easier to trace the origin of crises when they are narrowly defined (a composite index likely has very heterogeneous explanations). Noticeably also, not all recent evidence yields disappointing results: Obstfeld, Shambaugh and Taylor (2009) could successfully explain exchange rate movements during the crisis using appropriately scaled reserve ratio's.

Beyond these issues, there seems to be a more fundamental problem with early warning signals, which can be summarized as follows: on the one hand, early warning signals are meant to predict crises with the aim to avoid their occurrence; on the other hand, if the signals are used for policy purposes, the predicted crises will be avoided, which means that model predictions will not be accurate any longer. There is therefore a contradiction between the aim to predict crises and that of avoiding crises, which casts doubt on the usefulness of EWS models for policy purposes: if we follow the argument, early warning signals cannot work effectively to forecast crises. This argument is somewhat reminiscent of the Lucas critique, but to our knowledge has not been explicitly spelled out. We refer to this as an “impossibility theorem”<sup>4</sup>: crises *cannot* be predicted, to the extent that predicting them will trigger a policy reaction that will prevent them.

Aside from this “impossibility theorem”, another problem may arise, which is similar in essence because it touches upon rational expectations, but leads to the opposite conclusion: while the “impossibility theorem” implies that early warning signals cannot work, one may fear that they work too well and lead to self-fulfilling prophecies. Indeed, if EWS models were to signal a crisis in a given country (for instance, a currency crisis), market participants will likely react and sell the currency, which would precipitate the crisis. According to this second criticism, early warning systems would not be useless but dangerous, as they would lead to self-fulfilling prophecies and trigger crises. The danger of self-fulfilling prophecies has been acknowledged by policy makers, for instance in the context of the creation of the European Systemic Risk Board (*“The issues potentially addressed in the warnings and recommendations will be extremely sensitive and we must be careful about adverse effects, such as the warnings turning into self-fulfilling prophecies by frightening financial markets. The decision whether or not to publish will, therefore, require a case-by-case decision after a careful assessment of the potential consequence”*).<sup>5</sup>

The aim of this paper is to present and discuss these fundamental arguments against early warning systems. This paper can therefore be understood as a defense of early warning signals. It proceeds in two steps. First, the paper discusses the general arguments against the use of EWS models; second, the paper illustrates the ability of a simple currency crisis model (Bussière and Mulder, 1999) to perform well, out-of-sample during the latest, and most severe general crisis episode since the great depression. The general arguments in favor of EWS models (and why the “impossibility theorem” may fail) are as follows. First, one assumption for the “impossibility theorem” to hold is that EWS are maintained and credible enough to trigger a policy reaction. Ironically, however, the credibility of EWS models tends to be low, and diminish over time as the memory of the previous crisis fades. The same argument also applies to the “self-fulfilling prophecies” concern, which assumes that market participants take action

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<sup>4</sup> With apologies to Arrow (1950), who used the term in a different context.

<sup>5</sup> See on-line discussion:

<http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/09/405&format=HTML&aged=0&language=EN&guiLanguage=fr>

upon reception of the signal: this assumes that market participants follow such signals very closely and take them for granted, a rather strong assumption.<sup>6</sup> A second argument stems from the political economy of currency crises and from the costs associated with preventive measures: even if EWS models are taken seriously, nothing guarantees that policy makers will take action upon them, depending on their own incentives. For instance, the occurrence of elections tend to delay reforms, and empirically, these political economy factors seem to play an important role in the unfolding of currency crises (see Bussière and Mulder, 2000). The willingness to take actions may erode over time. While reserve coverage ratios increased dramatically following the Asia crisis, they have been declining in recent years.

Aside from these general arguments, the case for EWS models can also be made by showing that the out-of-sample performance of existing models is not as bad as commonly assumed. We do this in the paper by means of a simple example. The paper presents out-of-sample predictions of a parsimonious currency crisis model (Bussière and Mulder, 1999): this model was already shown to work well in an out-of-sample exercise for the European Monetary System crises of the early 1990s (see Eichengreen, 2001); it is applied here, out-of-sample, to the depreciation episodes that took place at the end of 2008, in the wake of the financial crisis. The exercise is conducted for a group of 21 emerging market and new EU economies, using the same model as originally published. Specifically, the model aims to relate a crisis index (which is calculated as a weighted average of the exchange rate depreciation and of the loss in reserves, between September and December 2008) to three key fundamentals: the current account balance, the degree of exchange rate over-valuation and the ratio of short-term debt to international reserves. The simplicity of the model makes it very tractable and lends itself very well to this exercise. Results indicate that the countries that recorded, prior to the crisis, high short-term debt compared to international reserves, a large current account deficit, or a sharp exchange rate appreciation, were those that experienced the strongest exchange market pressure. Having said that, we also have several outliers, corresponding to Type I as well as Type II errors (i.e., missed crises and false alarms). We argue, however, that even these cases are useful, because they inform us further on the causes of currency crises and structure the debate, which a mere judgmental analysis cannot achieve. To take a medical analogy, we would argue that EWS models play an important role in establishing the “differential diagnosis” of currency crises. The paper focuses on the example of Hungary.

The rest of the paper is organized as follows. Section 2 reviews the literature and discusses some very general arguments in favor and against the use of early warning systems, including the “impossibility theorem”. Section 3 presents results from the model outlined in Bussière and Mulder (1999), applied to the period from September to December 2008. Section 3 concludes and discusses the application of EWS models for policy purposes as well as the most appropriate way to communicate EWS results as part of the macroprudential surveillance framework.

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<sup>6</sup> Another obvious condition for self-fulfilling prophecies is that the signals are made public; strict confidentiality can likely avoid such issues. We will however return to the most appropriate way to communicate EWS results in the conclusion.

## 2 The “impossibility theorem” and self-fulfilling prophecies: some general arguments in favour and against the use of early warning signals

### 2.1 A brief review of the literature

The literature on currency, banking, and financial crises is too vast to be reviewed here. The aim of this short section is not to be exhaustive, but rather to recall some of the most prominent papers on the subject, as well as the criticism expressed in Berg and Pattillo (1999a). There exists, to date, a broad variety of models that qualify as “early warning systems”. These models are applied to detect currency crises (Sachs, Tornell and Velasco, 1996), banking crises (Demirguc-Kunt and Detragiache, 1998), “twin” (i.e., banking and currency/balance of payments) crises (Kaminsky and Reinhart, 1999), asset price boom/bust cycles (Alessi and Detken, 2009), etc. The statistical methods vary considerably. Several papers use discrete choice models like the logit (Bussière, 2007) or probit (Frankel and Rose, 1996) models, while others use a continuous index (Sachs, Tornell and Velasco, 1996). Kaminsky and Reinhart (1999) use signals sent by individual indicators (depending on whether they cross a certain threshold). All these papers also use different explanatory variables (called in this context early warning indicators).

It appears that even prominent papers on the subject do not have a very good out-of-sample performance. Berg and Pattillo (1999a) evaluated the performance of three leading papers, by Frankel and Rose (1996), Sachs, Tornell and Velasco (1996) and Kaminsky, Lizondo, and Reinhart (1998). They used the models as originally published, updated the explanatory variables, and compared the outcome with the actual crisis index. The results are, in the words of the authors, “mixed”, such that they reach the following conclusions: *“Plausible modifications to this model improve its performance, providing some hope that future models may do better. This exercise suggests, though, that while forecasting models may help indicate vulnerability to crisis, the predictive power of even the best of them may be limited.”*

The criticism expressed by Berg and Pattillo (1999a) has had an influential impact on the profession and is often interpreted as an argument against the use of EWS. However, the finding that three prominent models fail to predict crises out-of-sample may just come from idiosyncrasies in these particular models and does not suggest that *all* EWS models are doomed to fail. In fact, the authors of the paper have themselves contributed to the literature and proposed their own methodology (Berg and Pattillo, 1999b). In addition, the results presented by Berg and Pattillo are not as strong against early warning signals as commonly perceived: after all, the Frankel and Rose model correctly predicts 90% of the observations, at a relatively low cost in terms of false alarms (to be completed). More recently, Frankel and Saravelos (2010) argue that EWS models performed well out of sample during the financial crisis (to be completed).

Finally, one should also point out that the alternative (judgement based decisions) may not be better: at least, early warning systems provide a quantified assessment that can be compared with actual outcomes and evaluated using statistical criteria. Judgements, by contrast, are rarely (if any) evaluated so thoroughly. The comparison between judgement-based and model-based predictions is therefore biased against models, simply because they lend themselves more easily to statistical evaluations. In addition, purely judgment based decisions may reflect the personal bias of the analyst, including herding behaviour. By contrast, early warning exercises based on statistical models are much more objective, given that they purely rely on statistical inference.

Still, there are more fundamental objections against early warning models, which Section 2.2 now turns to.

## **2.2 The “impossibility theorem”, self-fulfilling prophecies and other fundamental criticisms of early warning systems**

While the issues raised by Berg and Pattillo (1999a) are model-specific, a more fundamental problem arises with the whole concept of early warning signals, namely the view that it is impossible to correctly predict crises, because if a model reliably predict crises, there will be a policy reaction that will prevent the crisis. This argument is somewhat reminiscent of the Lucas critique; it is also akin to the Goodhart Law, according to which an indicator ceases to be useful when it is used for policy purposes.<sup>7</sup> However, to our knowledge, the argument has not been explicitly spelled out for the case of currency or financial crises (importantly also, we spell it out in the paper but take the contrarian view). Specifically, the “theorem” can be supported as follows. To begin with, let us recall that the aim of early warning signals is to predict crises, with the aim to avoid them. Next, the reasoning goes, if the signals are used for policy purposes, the predicted crises will be avoided, which means that model predictions will not be accurate any longer. There is therefore a contradiction between the aim to predict crises and that to avoid crises, which casts doubt on the usefulness of EWS models for policy purposes. We refer to this as an “impossibility theorem”. One implication of this would be that EWS models should not be used, because *by definition* they cannot work. We will return to this argument to point out why it does not necessarily hold; but before, let us consider another fundamental criticism addressed to EWS models.

Another problem with EWS is almost the opposite of the “impossibility theorem”, but also relates to rational expectations: while the “impossibility theorem” implies that early warning signals may not work, one may fear that they work too well and lead to self-fulfilling prophecies. Indeed, if EWS models were to signal a crisis in a given country (for instance, a currency crisis), market participants may react and sell the currency, which would precipitate the crisis. According to this second criticism, early warning systems would not be useless but dangerous, as they would lead to self-fulfilling prophecies and trigger crises.

## **2.3 Why the “impossibility theorem” and other fundamental concerns may fail**

The general arguments in favor of EWS models (and why the “impossibility theorem” may fail) are as follows. First, one assumption for the “impossibility theorem” to hold is that EWS are maintained and credible enough to trigger a policy reaction. Ironically, however, the credibility of EWS models tends to be low, such that the lessons from EWS models are not always taken seriously. In fact, one should also realize that EWS models are relatively costly to maintain, at least those with a large number of countries and variables. In practice, the fact that few currency crises happened after those of Argentina and Turkey in the early 2000s has led many researchers and policy institutions to turn to other tools and subjects, such that the signals sent out by EWS models –if any— were not very audible. At the same time false alarms were eroding the credibility of the Early Warning Systems, and may have led

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<sup>7</sup> “Any observed statistical regularity will tend to collapse once pressure is placed upon it for control purposes” (Goodhart, 1975). A related statement is that “a risk model breaks down when used for regulatory purposes”. (Dánielsson, 2002).

policy makers to take them less seriously. Similar arguments also apply to the “self-fulfilling prophecies” concern, which assumes that market participants take action upon reception of the signal. This assumes that private sector analysts maintain such models and that the results of the models lead to investment decisions. Also related to the risk of “self-fulfilling prophecies”, one assumption behind the argument is that the signals are made public; one obvious step to make is to ensure strict confidentiality to avoid such issues.

A second argument against the “impossibility theorem” stems from the political economy of currency crises: even if EWS models are taken seriously, nothing guarantees that policy makers will take action upon them, depending on their own incentives and constraints. If, for instance, a given government does not have a clear majority in the house, the reforms necessary to avoid the crisis may be delayed, or simply abandoned. In addition, taking preemptive action bears a financial, but also a political cost, and the policy maker needs to weigh the costs and benefits of implementing the necessary reforms. The financial cost of avoiding crises is clear. All measures aiming at averting a crisis are costly, such as borrowing reserves, reforming the financial sector, or raising interest rates. Yet, in addition, there are substantial political costs. The latter may arise from the stigma attached, for instance, to IMF programs<sup>8</sup>. The reputation of the policy maker may be endangered by undertaking a reform, such as the reform of the financial system, especially that the costs of the crisis itself are not visible until the crisis has happened. For that reason, to the extent that reforms typically have benefits in the long run but costs in the short run, the occurrence of elections tends to delay reforms. Empirically, these political economy factors seem to play an important role in the unfolding of currency crises (see Bussière and Mulder, 2000). In that paper, a standard EWS model very similar to the one presented here was augmented with political variables, which turned out to be significant. The variables included the occurrence of elections and the stability of the government, proxied by various measures of political stability borrowed from the literature on political science. In fact, this very much calls for the use of political variables in early warning signals, in complement to economic variables.

## **2.4 In defense of early warning systems**

In the introduction we have discussed various fundamental criticisms of EWS models, the impossibility theorem and self-fulfilling prophecies. In this section we would like to discuss additional benefits of EWS models, which are not related to the above.

One key benefit of EWS models, in our view, is the disciplining effect that they bring into economic reasoning. Indeed, unlike judgement-based assessments, EWS models provide a quantifiable assessment of economic vulnerability, which is statistically linked to measurable fundamentals. There are clearly costs and benefits in using EWS. The costs associated with EWS relate to the fact that they constrain the researcher who operates them to regularly update a number of economic variables and to update the model. This represents an opportunity cost compared to other approaches (such as actively reading the press or talking to people in the field). However, it is not clear how relevant these other approaches really are: reading the press may provide a lagging, rather than a leading, indication of the risks, and talking to market participants may be also lagging: if market participants believe that a crisis

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<sup>8</sup> For example, according to a senior economic adviser in the South Korean government (Shin Hyun-song) "If you are seen going to the IMF, then this is a very strong sign that your economy is going very badly wrong", July 24, 2010 (<http://finance.yahoo.com/news/SKorea-IMF-work-on-emergency-apf-2187360675.html?x=0&v=2>). [More references here?](#)

will happen, it is probably too late to avoid it. Of course, this does not mean that economists should not read the press or talk to market participants: the EWS approach can be completed by other approaches, our point is that “exercising judgment” may prove insufficient.

In addition, it is not clear how to aggregate the information provided by different sources without a clear model, something that EWS do provide (in the form of a continuous indicator, or the probability of having a crisis in a given time window). The fact that EWS model yield a quantifiable assessment lends itself to regular evaluation, and reduces the ability to manipulate the system to avoid politically unwelcome messages—conclusions that a country is vulnerable are generally not welcomed by the governments of the effected countries even when they come behind closed doors.

We also would like to highlight the fact that even “wrong” results (Type I and Type II errors) are informative. Indeed, missed crises should not imply that EWS are useless: rather, they imply that the factors behind them were not those included in the model. For example, the fact that models for which the government budget balance played a key role failed to predict the Asian crisis contributed to rule out the hypothesis that this crisis was a so-called “Generation I” crisis (as outlined in Krugman, 1979). This led researchers to investigate other channels and causes of the crisis, which in turn accelerated the policy response. As demonstrated in Section 3 of this paper, “wrong calls”, i.e. missed crises and false alarms, are useful information. Missed crises suggest that other factors (than those included in the model) played a role in the crisis. False alarms suggest that unknown factors may play a beneficial role for a given country. In both cases, this should help analysts and policy makers make a better informed decision. To summarise, we would argue that EWS models play an important role in establishing the differential diagnosis of currency crises.

## **2.5 Testable implications.**

The discussion of the impossibility theorems suggest there are several testable implications: if the impossibility theorem holds and policy makers take actions based on the EWS model we will likely observe a significant decline in the number of crises, and if crises do occur they should not be explained by the EWS model. This would be accompanied by general improvements in the values of the variables (e.g. increased reserve buffers). If, on the other hand, the EWS model becomes self-fulfilling, then we will observe a much better performance of the early warning signals, with possibly some shift in the levels that trigger crises (e.g. relatively lower reserve coverage ratios trigger a crisis).

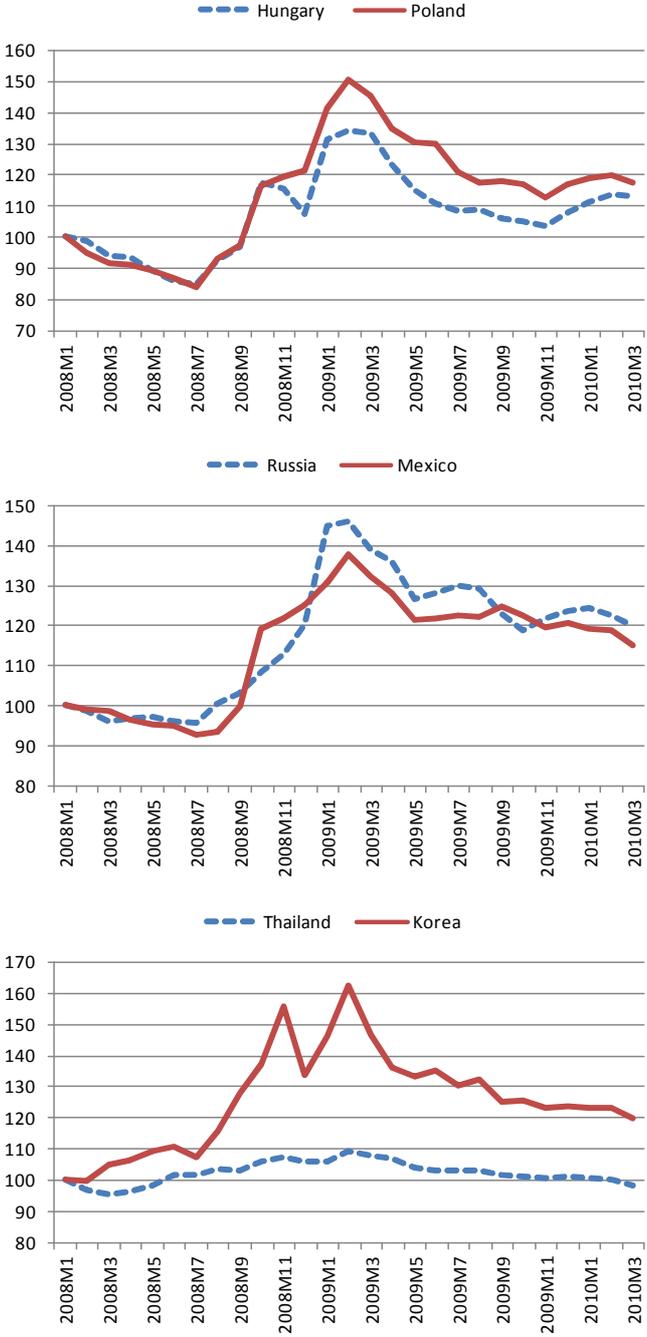
While checking these implications is beyond the scope of the paper, the accumulation of reserves as observed in the 2000s provides suggestive evidence that policy makers did draw lessons from the evidence provided by the models. In addition, the fact that even countries with sizeable levels of international reserves experienced exchange market pressure in late 2008, and sometimes even had to use swap lines with the Federal Reserve, also provides indirect evidence that some of the mechanisms behind the “impossibility theorem” are at play. However, a systematic investigation tends to show that, by and large, the standard variables use in EWS were good predictors of the sharp depreciations recorded in the wake of the 2008 crisis. This is what Section 2.5 now turns to.

## **3 Early Warning Signals in practice: lessons from a simple model of currency crises, applied to the 2008 financial crisis**

In this section, we set out to use a model estimated some ten years ago and apply it, out-of-sample, to the crisis episodes that burst out in the wake of the 2008 financial crisis. The model presented here

(Bussière and Mulder, 1999) lends itself very well to this exercise because of its simplicity and tractability.<sup>9</sup> The results will therefore be very easy to duplicate for whoever works in the field of international macroeconomics.

Figure 1: Bilateral Exchange Rates of Selected Economies with the US Dollar.  
*Indices: 2008M1 = 100; source IMF IFS ; an increase indicates a depreciation.*



<sup>9</sup> The model and its results helped to underpin the IMF’s general policy advice on the reserve cushions that countries need to maintain to reduce their external vulnerability (IMF 2000). The results gained considerably in credence because the different approach used by Berg and Patillo 1999a led in essence to the same core set of parsimonious variables.

The period following the collapse of Lehman Brothers lends itself particularly well to this exercise in view of the very sharp depreciations associated with the financial crisis (Figure 1). Indeed, starting in the Fall of October 2008, the currencies of several emerging market and new EU economies depreciated by a very substantial amount (Thailand being a noticeable exception).

### 3.1 A simple model: Bussière and Mulder (1999)

The framework presented in Bussière and Mulder (1999) is very similar to that of Sachs, Tornell and Velasco (1996). One key specificity of this framework is that the aim is not to predict the timing of crises but rather to evaluate, at a given point in time, which countries are most vulnerable. For this reason, the econometric specification does not rely on panel estimation with both a time and country dimension (as, for instance, in Bussière, 2007) but rather on cross-sections. The dependent variable is a continuous index computed over a certain period of time during which exchange market pressure was intense, while the explanatory variables enter the specification with a lag. In the published paper, the model was estimated, first, during the crisis periods 1994M11-1995M4 and 1997M5-1997M10. It was then tested out-of-sample for the period 1998M7-1998M10. Finally, the model was estimated for all three periods together; this is the specification that we are using in the present paper.

In the original paper several variables and specifications were tested, including the real effective exchange rate appreciation, the current account balance, the ratio of short-term debt to international reserves, the so-called “lending boom” variable (defined as the increase in the credits to the private sector), export growth, various liquidity ratios, and the presence or not of Fund programs. The aim was partly to test the model of Sachs, Tornell and Velasco (1996), and partly to look for alternative explanatory variables and specifications. In the present paper, by contrast, our aim is just to take an existing model and test it out-of-sample, without re-estimating the model (the point is to illustrate the out-of-sample performance of an existing model, not to look for in-sample goodness of fit, given the point made by Berg and Pattillo, 1999a). For this reason, we choose the most simple specification of the paper, which is as follows:

$$\text{Crisis index} = \alpha_0 + \beta_1 \text{RERINS} + \beta_2 \text{STD/R} + \beta_3 \text{CA/GDP} \quad (1)$$

Where:

- The crisis index is a weighted average of the real effective exchange rate and of international reserves. The weights are equal to the precision of the series in the ten years preceding the start of the crisis window. The latter was taken during 1994M11-1995M4, 1997M5-1997M10, and 1998M7-1998M10 when the model was estimated. This time, we apply our model to the period 2008M9-M12 and therefore take our independent variables before August 2008 (in the case of quarterly data, such as the current account over GDP, we use 2008Q2).
- RERINS is the *depreciation* of the real effective exchange rate in the 48 months preceding the start of the crisis window: the rationale is that a country that saw a sharp appreciation is likely to experience a large crisis index, hence a negative sign is expected.<sup>10</sup>

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<sup>10</sup> Note that it may be more intuitive to measure the degree of *appreciation* and expect a *positive* sign; the choice was made to compare results more directly with Sachs, Tornell and Velasco (1996) and obviously does not matter.

- STD/R is the ratio of short-term debt to banks to international reserves, taken prior to the start of the crisis window (a positive sign is expected: the higher the level of short-term debt, or the lower the level of reserves, the higher the expected crisis index).
- CA/GDP is the current account *deficit*, measured as percentage of GDP, also taken prior to the start of the crisis window (a positive sign is expected: a larger deficit should be associated with higher exchange market pressures).

The estimation yielded the following coefficients (all were significant at conventional levels, see results in Bussière and Mulder, 1999, p. 32, Table 8, column (5); the adjusted R<sup>2</sup> was 0.48):

$$\text{Crisis index} = -20.78 - 0.38 * \text{RERINS} + 0.28 * \text{STD/R} + 1.67 * \text{CA/GDP} \quad (2)$$

Can this simple model explain developments ten years after the model was estimated? This is what Section 3.2 turns to.

### 3.2 Out-of-sample predictions during the 2008 financial crisis

Table 1 reports the actual and predicted crisis indices for the 21 countries originally included in Bussière and Mulder (1999). Before comparing the actual and predicted crisis indices, a few words on the crisis index *per se* are in order (Table 1).

**Table 1: Actual and Fitted Crisis Indices**

Rank (Actual)	Actual Index	Country Name	Fitted Index	Rank (fitted)	Code
1	37.0	Poland	8.2	8	PO
2	27.9	Russia	-11.3	19	RU
3	27.5	Sri Lanka	23.5	3	SL
4	27.1	Brazil	23.6	2	BR
5	20.4	Korea	3.4	9	KO
6	19.8	Mexico	1.6	11	MX
7	19.5	Turkey	25.9	1	TU
8	16.3	Indonesia	-2.3	14	ID
9	16.2	Hungary	17.2	5	HU
10	14.8	Chile	19.2	4	CH
11	14.6	India	-3.8	16	IN
12	11.6	South Africa	-0.7	13	SA
13	11.5	Peru	-3.7	15	PE
14	10.7	Pakistan	2.8	10	PA
15	8.6	Malaysia	-35.9	21	MA
16	8.1	Argentina	-6.1	17	AR
17	7.9	Colombia	12.7	6	CO
18	5.1	Philippines	-0.7	12	PH
19	0.0	Jordan	10.3	7	JO
20	-0.3	Thailand	-7.9	18	TH
21	-17.2	Venezuela	-22.9	20	VZ

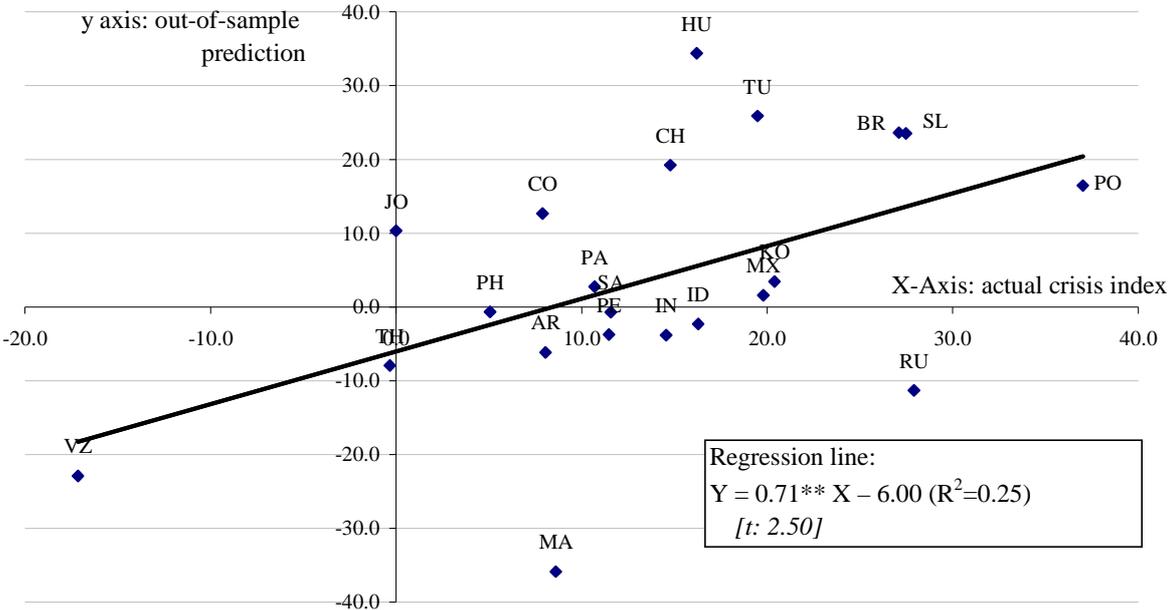
A quick glance at the top 10 countries reveals the strong heterogeneity among the countries most severely affected by the 2008 financial crisis, which belong to very different regions, such as Eastern Europe (Poland, Russia, Hungary), East Asia (Korea, Indonesia), Latin America (Brazil, Mexico, Chile), as well as Sri Lanka and Turkey. Unlike the 1994 Tequila crisis and the 1997 Asian crisis,

which affected predominantly Latin America and East Asia, respectively, the 2008 crisis does not have such strong regional component.

The comparison between the actual and fitted (predicted) indices shows that the correlation between the two is about 0.5, which is somewhat encouraging given some outliers (which we will come back to below). A simple regression on the actual and fitted indices using ordinary least squares returns a positive coefficient of 0.71, which is significant at the 5% level (Figure 2). Importantly also, the ranking of the countries is similar, as revealed by looking at the Spearman rank order correlation (at 0.42, significant at the 5% level).

**Figure 2: Correlation Between Actual and Predicted Indices.**

*Regression using ordinary least squares. Country codes are included in Table 1.*



*Authors' calculations.*

Overall, therefore, we find it very encouraging that such simple model, which includes only three very standard variables in a linear specification, can correctly predict the ranking of the countries most subject to exchange market pressure, some ten years after publication of the original paper.

Having said that, we also have significant outliers. On the positive side (meaning, among the countries for which the model over-predicts the crisis index, i.e. “false alarms”), there is Hungary. The fact that the model predicted such large crisis index stems from one variable in particular: Hungary registered a large current account deficit, nearly 8% of GDP in the first half of 2009. On the negative side (meaning, among the countries for which the model under-predicts the crisis index, i.e. “missed crises”), there is Malaysia. For Malaysia, like for Hungary the current account balance is the variable that contributes most to the assessment. However, it plays in the opposite direction, given that Malaysia had a very large surplus before the crisis (over 17% of GDP). In addition, the ratio of short-term debt to reserves was low for Malaysia, about one third. This explains why, while the actual crisis index was not very high (at 10), we under-predict its magnitude by computing a negative number. This suggests that other factors, not accounted for in our simple model, were at play to explain the crisis index in Malaysia. Noticeably, many countries with high levels of reserves experienced severe market pressure in the wake of the 2008 financial crisis.

Interestingly, the coefficient of the regression is significantly below 1, at 0.71. This suggests that on average, the model under-predicts the magnitude of the crisis indices, even though it does predict the ranking correctly. In other words, there must have been some factors that contributed to the crisis *globally* and that were not accounted for in the model. A possible explanation is that this crisis was the first global crisis and that contagion (not accounted for in this model) played a key role. Whereas many observers anticipated a depreciation of the US dollar, the dollar appreciated during the crisis, due to higher risk aversion globally (US investors repatriated their foreign investments, while foreign investors also sought low risk investments such as T-bills).

One final remark on these outcomes is that running a regression line between actual and fitted crisis indices, as done above (and as common in the literature), or looking at correlation coefficients, implicitly assumes that we weigh Type I and type II errors equally. A risk averse economist may prefer to over-predict the crisis index (as we did for Hungary) than to under-predict it (as we did for Malaysia), which ordinary least squares do not take into account.

### 3.3 Further Extensions

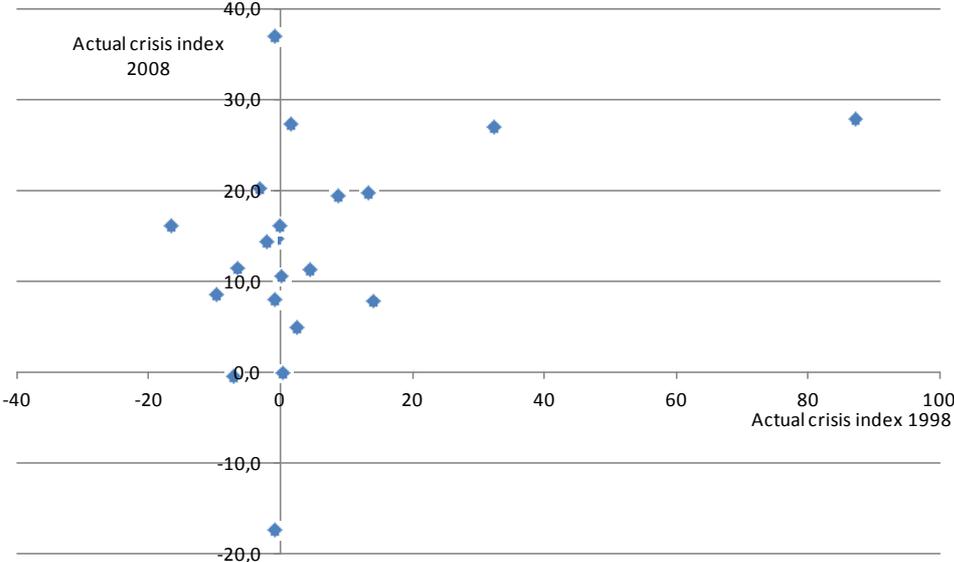
The above exercise can be extended in a variety of directions. First, one may wonder whether the 2008 crises actually reflect past crises, such as those that affected emerging market and new EU economies in the 1990s. Is it the same countries that are always stricken by currency crises? To investigate this, we ran simple regressions of the crisis indices for 2008 against those of the years 1994, 1997 and 1998. As Figures 3 demonstrates, the indices are not correlated.

This simple regression of course omits one key element, namely the fact that fundamentals were not equal then and now. To control for this, we ran regressions of the *residuals* of the 2008 crisis indices on the *residuals* of the past crisis episodes. These residuals capture the part of the crisis indices that is orthogonal to fundamentals (the idiosyncratic components). Again, it turns out that such regressions do not yield significant coefficients (Figure 4), which suggests that idiosyncratic (non-measurable) components do not play a first order role in the unfolding of crises. This is good news for work on early warning signals because it suggests that the errors of the model are not systematic.

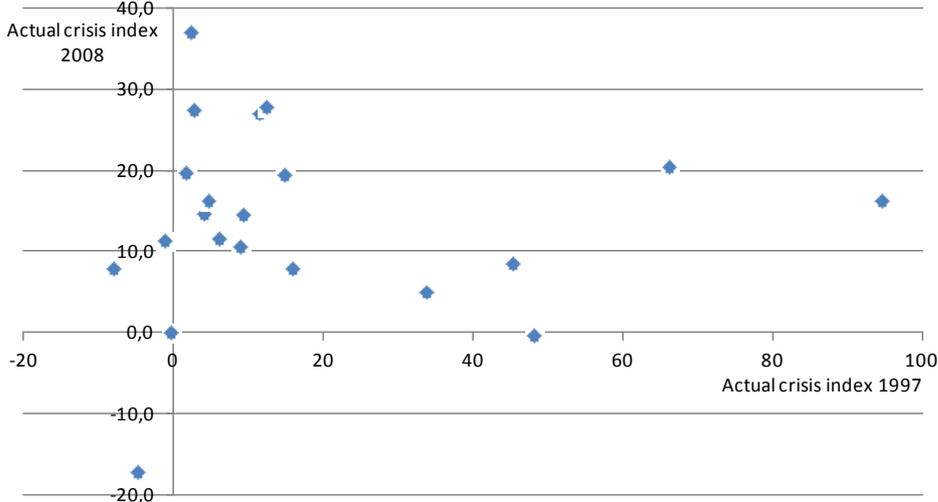
In a final extension, we calculated the actual and fitted indices for a set of countries not included in the original paper (using exactly the same model as then). This new group of countries includes EU states, as well as candidate countries; this is therefore a true “out-of-sample” exercise, since not only the model was not re-estimated, but the original sample did not even contain this group of countries. The results are very good, especially for Bosnia and Herzegovina, the Czech Republic, Lithuania and the Slovak Republic. For the other countries, by contrast, the model tends to over-predict the crisis index. One possible explanation would attribute a protective to for the European Union, either through actual mechanisms (such as EU supported programs) or a signalling effect.

**Figure 3: Comparison of the Crisis Indices, 2008 Crisis with Previous Crises**

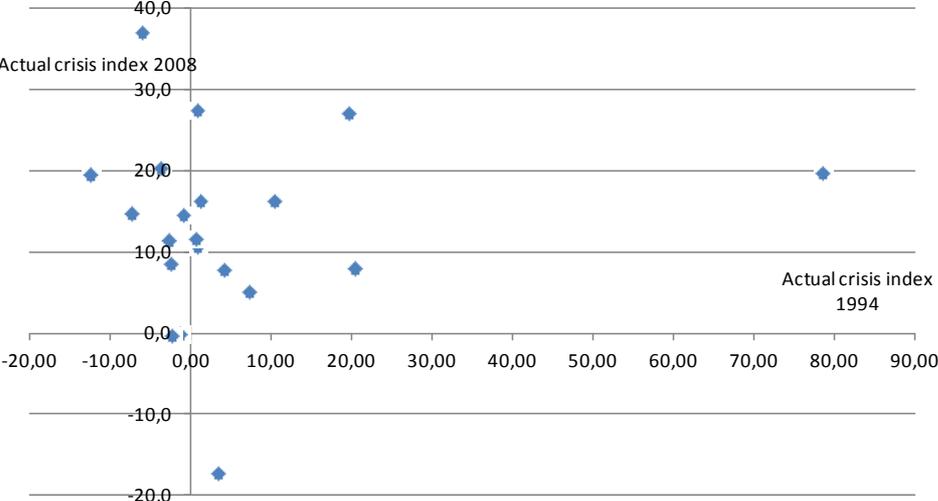
**Panel A: Comparison with 1998 crisis**



**Panel B: Comparison with 1997 crisis**

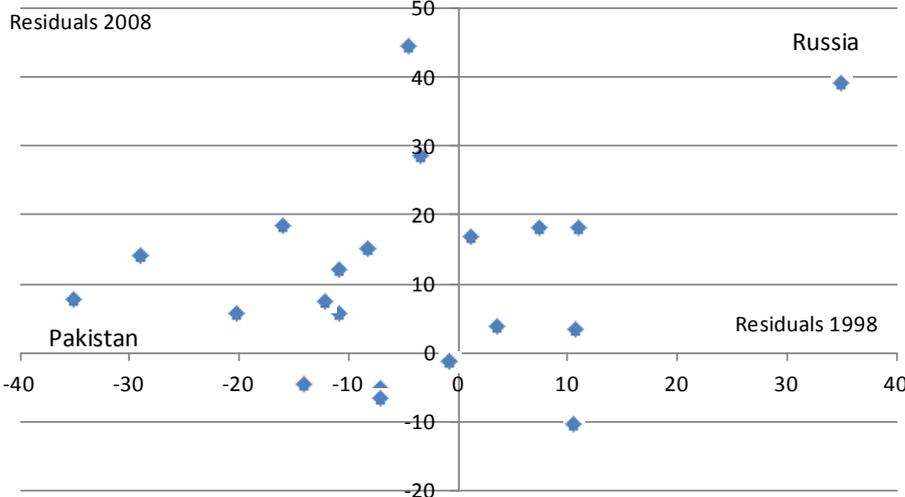


**Panel C: Comparison with 1994 crisis**

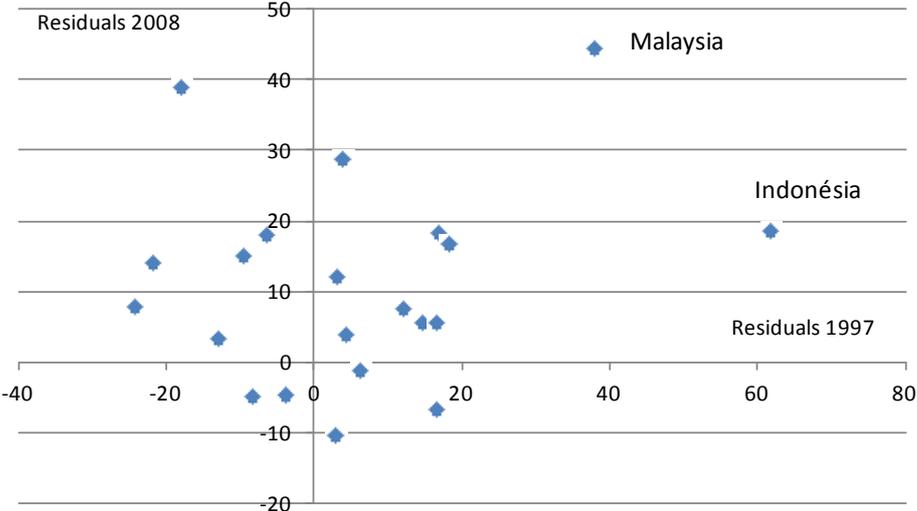


**Figure 4: Comparison of the Crisis Index *Residuals*, 2008 Crisis with Previous Crises**

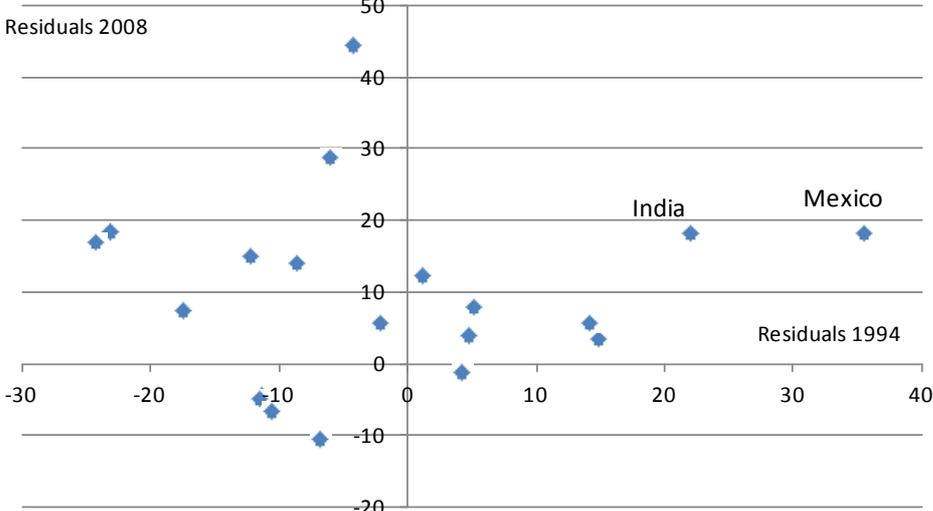
**Panel A: Comparison with 1998 crisis**



**Panel B: Comparison with 1997 crisis**



**Panel C: Comparison with 1994 crisis**



**Table 2: Actual and Fitted Indices, Additional Countries**

	Actual	Fitted
Bosnia & Herzegovina	12,4	20,8
Bulgaria	12,0	49,8
Croatia	12,6	37,6
Czech Republic	14,3	15,7
Estonia	10,7	43,1
Latvia	10,4	59,2
Lithuania	10,4	32,3
Romania	22,5	40,7
Slovak Republic	9,2	5,1

#### 4 Conclusion

The aim of this paper was to discuss the benefits of early warning signals and illustrate their merits by considering the out-of-sample performance of a very simple EWS model of currency crises, using a panel of emerging market and new EU member states. The paper discussed in particular the view that early warning signals cannot work by definition, due to what we call an “impossibility theorem”. According to this extreme view, EWS models *cannot* perform due to a fundamental flaw: if such model could effectively predict crises, policy makers would use it to avoid crises, which would remove the explanatory power of the model. In other words, if we follow this argument, the endeavour to predict and avoid crises is doomed from the start. Another fundamental criticism addressed in this paper is that EWS models are actually dangerous, because they may lead to self-fulfilling prophecies: if market participants were to receive signals that a crisis is looming in a given country, their reaction would immediately trigger a crisis, independently of the quality of the signal.

The paper has, first, argued against this view by considering very general arguments. In particular, the political economy of financial crises may lead policy makers to postpone the reforms that would avoid crises. In addition, the “impossibility theorem” and the “fulfilling prophecies” arguments assume that EWS models are regularly maintained and taken seriously, which is currently far from being the case. One implication of the risk to see self-fulfilling prophecies is the need to communicate EWS results appropriately. This is not an easy task. On the one hand, if EWS results are never communicated (i.e. kept confidential), this may avoid self-fulfilling prophecies altogether. Yet, there is always a risk that the results leak out, or even more simply than another analyst replicates the model and communicates the results. A better strategy is perhaps therefore to communicate the results frequently, which would imply smoother transitions. Frequently communicating EWS results would ensure that self-corrections happen as soon as fundamentals deteriorate. Ideally, therefore, the impossibility theorem would be avoided without triggering self-fulfilling prophecies: in this “perfect” world, fundamentals would always be in the green zone, and EWS would correctly predict no-crisis.

The paper has also shown whether a simple model designed to explain currency crises, published ten years ago (Bussière and Mulder, 1999), was able to predict the exchange market pressure that impacted emerging market and new EU economies at the end of 2008. The results were very encouraging, showing that this simple model could satisfactorily predict the ranking of the most vulnerable countries. Clearly, however, the model also made “Type I” and “Type II” mistakes: it

under-predicted the crisis index of some countries (noticeably, Malaysia) and over-predicted that of others (noticeably, Hungary). We argue that even these errors are useful, because they point to other factors than those included in the model and contribute to a deeper understanding of the crisis. The main objective of this section –and of the paper- was not to pretend that a simple model can predict crises perfectly, but rather to show that even a parsimonious specification can do a relatively good job at explaining economic vulnerabilities, out of sample. It was also to show how a simple model can be used for policy purposes. We hope that this paper has contributed to a better understanding of EWS models and to their wider acceptance in the profession.

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## Data Appendix

The data sources are the same as in Bussière and Mulder (1999); we therefore would like to refer the reader to this paper for detailed information on the variables. In a nutshell, the data sources are as follows:

### **1. Crisis index.**

The crisis index is weighted average of the depreciation of the exchange rate and the loss in reserves, weighted by the precision (the inverse of the variance) of these two variables measured over ten years. The exchange rate is taken from IFS line rf, the nominal bilateral exchange rate against the dollar (period average). Reserves are taken from IFS line 1L.d, reserves minus gold.

### **2. Current Account**

The current account variable is expressed as a percentage of GDP and refers to the ten year period ending before the crisis. We used quarterly data from IFS line 78ald. Quarterly data on GDP were interpolated based on annual data (IFS line 99b).

### **3. Exchange Rate Depreciation.**

The exchange rate is the real effective exchange rate. We took the ten years preceding the crisis.

### **4. Short-term debt to reserve ratio.**

To compute this ratio we took the same reserve variable as in point 1 above. For short-term debt we used the consolidated short-term debt data published semi-annually by the Bank of International Settlements. These data refer to the international positions of reporting banks on countries outside the reporting area and are defined on a remaining maturity basis.