

A REVIEW OF EARLY WARNING SYSTEM MODELS

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1. Introduction

“Any early warning system to detect impending dangers to the world economy must find a way of bringing together the scatter of international and national macrofinancial expertise. We at the Fund have already begun intensifying our early warning capabilities and will be strengthening our collaboration with others involved in this area.”¹

After a relative stability in the post-World War II period, the world economy has again become familiar to financial crises following the collapse of the Bretton Woods system.

The first wave of the currency and debt crises that occurred particularly in Latin American countries in early 1980s was first followed by the 1992-1993 European exchange-rate mechanism (ERM) crisis and then by the two large-scale crisis episodes: the collapse of the Mexican peso at the end of 1994 and the consecutive financial crises in East Asia that began with the devaluation of Thai baht in July 1997 and induced a chain reaction in many Asian economies. The common characteristic of these two crises is their tendency to spread to other economies (contagion). However, the latter created much more external consequences, affecting the whole global economy, while the former had only a regional impact. The series of crises continued on with the violent devaluation of the Russian ruble in August 1998, the outbreak of the

Brazilian currency crisis in early 1999 and the eruption of the Argentinean financial crisis in 2001-2002. This global economic and financial instability context of the 1990s 2000s affected the Turkish economy as well which suffered from two severe crisis episodes in April 1994 and February 2001, and two relatively less severe currency crises in May 2006 and October 2008. These striking and recurrent crisis episodes stimulated a large discussion on the theoretical specification of the crisis models on the one hand, and on the empirical analyses that aim at identifying the causes and origins of the crises on the other hand.²

Financial crises have not declined in number, frequency or severity over the last two decades, rather the contrary (Bordo et al., 2001). Each crisis causes enormous costs in the countries concerned. Even if many crises may help to promote overdue structural change, they are costly and it is a worthwhile objective to realize adjustments without this heavy toll. Thus, international financial institutions invest in researching early warning systems (EWS). There is now a wide range of studies available, however, without real converging results: studies vary in coverage of countries and time, they apply different methods and they may even define crises quite differently.³

¹ Letter from IMF Managing Director Dominique Strauss-Kahn to the G-20 Heads of Governments and Institutions, 2008.

² Ali Ari, “An Early Warning Signals Approach to the Currency Crises: The Turkish Case”, 2009, p.2.

³ Daniela Beckmann, Lukas Menkhoff, Katja Sawischlewski, “Robust Lessons about Practical Early Warning Systems”, Discussion Paper No. 322, 2005, ISSN: 0949-9962, p.2.

2. Short review of the crisis literature

The recurrent crisis episodes since the collapse of the Bretton Woods system led to a flourishing crisis literature. Following the first wave of currency crises, in particular those that came out in Latin America in the late 1970s and the early 1980s, Krugman (1979) and Flood and Garber (1984) developed the so-called first generation crisis models in which currency crises are linked to persistent economic imbalances (large and growing fiscal deficits and/or gradual domestic credit growth) that are in conflict with a fixed exchange rate regime. Actually, the monetization of the persistent fiscal deficits in the fixed exchange rate regime leads to domestic credit growth and in parallel to gradual loss of foreign exchange reserves of the government. When the reserves stock reaches a critical threshold, investors perfectly know that the domestic exchange rate is no longer sustainable. Investors attack then the domestic currency in order to avoid capital losses due to a possible devaluation. Here, the investors' "rational" reaction triggers the currency crisis; however, the crisis would break out even in the absence of a speculative attack when the government foreign exchange reserves are "naturally" exhausted.⁴

The second-generation models were developed after the currency crises in the European Monetary System 1992-1993 and the crisis in Mexico 1994-1995. They explicitly accounted for authorities' policy options to defend the exchange rates and its related costs. Models of this generation are closely linked with the seminal work of Obstfeld (1986), who introduces the impact of rational expectations of investors into his approach. It implies that a market can reach an equilibrium with favourable as well as adverse economic fundamentals depending on the expectations of

investors and their respective actions (i.e. multiple equilibria are possible). The monetary and fiscal policies are assumed to be exogenously set.⁵

In these so-called second generation models, a crisis can be triggered without *ex ante* significant deterioration of macroeconomic fundamentals in contrary to first generation crisis models. Therefore, even if economic policies are consistent with the fixed exchange regime, a speculative attack may occur while investors shift their expectations towards the sustainability of the exchange rate. Unlike the first generation models where policymakers are supposed to have a mechanical and simplified behavior against a speculative attack (selling international reserves and then floating the peg when the reserves stock is exhausted); in the second generation models policymakers are supposed to have an optimizing behavior by adapting their policy to the shift of the investors' anticipations. That means when policymakers face a speculative attack, they decide to maintain or to abandon the peg after comparing the costs of such policy decision. This may be defined as the government loss function. Indeed, here economic policies are not predetermined as in the first generation models, but they are adapted to the problems of the economy and to the investors' expectations about the macroeconomic fundamentals observed in period t , but also about the sustainability of the government policies in $t + 1$. This interaction between the government and investors creates multiple equilibria that may lead to the occurrence of self-fulfilling currency crises. In these models the exact timing of the crisis is unpredictable in contrary to the first generation models.

⁴ Ali Ari, "An Early Warning Signals Approach to the Currency Crises: The Turkish Case", 2009, p.8.

⁵ Michael Heun, Torsten Schlink, "Early warning systems of financial crises – implementation of a currency crisis model for Uganda", no. 59, HfB - Business School of Finance & Management, 2004, p.14.

The outbreak of the 1997 Asian crisis led to a reorientation of the crisis models. Several theoretical studies were then conducted in order to explain the characteristics of these violent and contagious crisis episodes that resulted largely from the banking sector weaknesses in a financially liberalized economy. In this sense, some modelers put forward the structural distortions such as implicit or explicit public guarantees and inadequate banking regulation system in the worsening of the financial vulnerability (Krugman, 1998 and Corsetti, Pesenti and Roubini, 1999). Others focus on the self-fulfilling nature of the Asian crisis by modeling the dynamics of the financial instability based on the Diamond and Dybvig (1983) bank runs model (Chang and Velasco, 1998, 2001). Some others formalize a financial fragility, due to an increase of short-term foreign debt, which may contribute to the occurrence of a financial crisis. The depreciation of the domestic currency deteriorates then the balance sheets of the firms whose bankruptcies lead to economic contraction (Krugman, 1999 and Aghion, Bacchetta and Banerjee, 2000). Finally, some make efforts to combine these different approaches (Irwin and Vines, 1999, 2003, Schneider and Tornell, 2000, Burnside, Eichenbaum and Rebelo, 2004). The very high costs of crises in terms of economic contraction, unemployment, and necessary financial restructuring process for the public sector (and also for the private investors in terms of capital losses) have led to a proliferation of empirical studies (developed mainly by scholars, international financial institutions, central banks and investment banks) beside the theoretical models that have tended to explain crisis mechanism. These empirical models have aimed to predict crises by assessing their potential economic and financial determinants, and also in some cases by measuring political risks and developments in global economy. These studies have been also

used by policymakers to prevent future crises by detecting their causes earlier. In this sense, they have been frequently called 'early warning systems' that are likely to inform policymakers (and investors as well) about the occurrence of a crisis in a near future.⁶

3. Practical Early Warning System models

What is an early warning system? An early warning system consists of a precise definition of a crisis and a mechanism for generating predictions of crises. Different researchers have adopted alternative approaches to address a number of conceptual and practical issues that arise concerning both the definition of a crisis and the means of predicting it.⁷

Previous early warning systems of currency crises have used methods that fall into two broad categories. One approach extracts early signals from a range of indicators (Kaminsky and Reinhart, 1999, Kaminsky, Lizondo and Reinhart, 1998, Goldstein, Kaminsky and Reinhart, 2000), whereas the other uses logit models (Frankel and Rose, 1996, Eichengreen, Rose and Wyplosz, 1995, Berg and Pattillo, 1999b).

The leading indicators approach first developed by Kaminsky and Reinhart (1996), and Kaminsky, Lizondo and Reinhart (1998) considers vulnerability indicators and transforms them into binary signals: if a given indicator crosses a critical threshold, it is said to send a signal. For instance, if the current account deficit (expressed as a percentage of the GDP) falls below a given threshold, this particular indicator flashes a red light. In the Kaminsky-Reinhart approach the level is chosen

⁶ Ali Ari, "An Early Warning Signals Approach to the Currency Crises: The Turkish Case", 2009, p.9-10.

⁷ Hali J. Edison, "Do indicators of financial crises work? An evaluation of an early warning system", International Finance Discussion Papers no. 675, Board of Governors of the Federal Reserve System, July 2000, p.4.

after a grid search that minimizes the noise-to-signal ratio. This approach represented a major contribution to the literature when it appeared. Yet, as discussed in a book review of Goldstein, Kaminsky and Reinhart (2000), it is not without pitfalls (Bussiere, 2001).

If one is willing to work with discrete choice models with continuous variables on the right-hand side, logit and probit models provide a valuable framework, especially in view of one of their characteristics.⁸

Others methods have been also used for developing early warning systems: OLS approach of Sachs, Tornell and Velasco (1996) and of Bussière and Mulder (1999a, 1999b), artificial neural network of Nag and Mitra (1999), Fisher discriminant analysis of Burkart and Coudert (2000) and Markov-switching approach of Abiad (1999, 2003).

The design of an early warning system requires considering the scope of the model (country coverage, choice of explanatory variables, and time dimensions), the definition of a crisis (the statistical dating of the crises) and the statistical methodology (signal extraction versus probit analysis).⁹

Regardless of the method adopted, the empirical models construct first a crisis index as the dependent variable in order to identify crisis episodes. Some modelers describe currency crises as large depreciation or devaluation episodes (Frankel and Rose, 1996 and Kumar, Moorthy and Perraudin, 2003 *inter alia*), while some others consider currency crises as instances where a currency come under severe speculative pressure (Eichengreen et al., 1994, 1995, 1996 and Kaminsky et al., 1998 *inter alia*). This second currency crisis

definition takes into account both the situations where speculative attacks lead to currency devaluation and where the authorities successfully defend the currency by intervening in the foreign exchange market and/or rising domestic interest rates.

After defining crisis dating mechanism, the next step of constructing an EWS consists in selecting the adequate methodology. The non parametric signaling approach aims to monitor whether some key variables tend to behave unusually prior the onset of a crisis. They firstly build a crisis index and secondly transform the early warning indicators of the model into binary signals by defining an "optimal" threshold for each indicator.¹⁰

Kaminsky (1999) puts forward the analysis by constructing leading composite indicators as a weighted sum of the signaling indicators, where each indicator is weighted by the inverse of its noise-to-signal ratio. These composite indicators provide some information on the vulnerability of an economy to an upcoming crisis.

Kaminsky et al (1998) use the signal approach to predict currency crises for a sample of five industrial and 15 developing countries during the years 1970–1995. In their study, an indicator exceeding a specified threshold is interpreted as a warning signal that a currency crisis may take place within the following 24 months. They find that variables with the greatest explanatory power include exports, deviation of the real exchange rate from trend, the ratio of broad money to reserves, output, and equity prices. The signal approach is further applied in Kaminsky (1999) and Brüggemann and Linne (2002a). Perhaps the most careful attempt to craft an early-

⁸ Matthieu Bussiere, Marcel Fratzscher, "Towards a new early warning system of financial crises", Working Paper no. 145, European Central Bank, Working Paper Series, may 2002, p. 10-11.

⁹ Daniela Beckmann, Lukas Menkhoff, Katja Sawischlewski, "Robust Lessons about Practical Early Warning Systems", Discussion Paper No. 322, Oktober 2005, ISSN: 0949-9962, p.3.

¹⁰ Ali Ari, "An Early Warning Signals Approach to the Currency Crises: The Turkish Case", 2009, p. 11-13.

warning system is found in Goldstein et al (2000).¹¹

However, as Edison (2003) states, the interpretation of the conditional probability of a future crisis based on the values of the composite indicators remains difficult. Besides, contrary to logit/probit non linear regressions, the signaling approach does not let itself to statistical tests and the estimated probabilities are less directly derived. Moreover, on loses some information when threshold levels are set for the indicators; for instance, an indicator does not give any signal even though it derives unusually from its trend, because it is just below the threshold, also once an indicator crosses the threshold, one cannot observe how deteriorated the indicator is. However, this approach presents an important advantage of giving policymakers an easily interpretable picture of problems of the economy by showing clearly which indicators exceed the calculated threshold level.¹²

Some of the problems in the signal approach are solved with limited dependent or discrete-choice models. This method uses logit or probit functions and the predicted outcome, i.e. probability of crises, is constrained between zero and one.

The discrete-dependent-variable approach (or non linear regressions) evaluates directly the conditional probability of a crisis given a set of early warning indicators (that are not transformed into binary signals and are included into the econometric analysis in linear way) contrary to the signaling approach which aims to observe the unusual behavior of the individual indicators (transformed to binary signals)

before the onset of a crisis and to evaluate ability of each indicator in forecasting crisis episodes.

This approach has the advantage of summarizing the information about the crisis probability in one easily interpretable number (0 in case of non crisis and 1 in case of the crisis). In addition, it considers all the early warning indicators simultaneously in a multivariate framework, observes marginal contribution of an each indicator and thus allows discarding the insignificant ones from the analysis. Furthermore, this approach lends itself to standard statistical tests that measure robustness of the estimation results. However, in this approach the interpretation of the estimated coefficients of the indicators remains difficult because of the non linear nature of the model. Also, unlike the signaling approach, it is unable to rank indicators according to their ability of forecasting accuracy.

Among the earliest studies of this type, Eichengreen et al (1996) use data from 1959 through 1993 for industrial countries to characterize the common causes for currency crises and illuminate the contagious nature of currency crises. Frankel and Rose (1996) use a probit model to estimate the probability of crisis in an annual sample of 105 developing countries covering the period 1971–1992. They note that currency crises tend to occur when growth of domestic credit and foreign interest rates are high, and FDI and output growth are low. Kumar et al (2002) concentrate on forecasting crises and use logit model to study currency crises in 32 developing countries during the years from 1985 to 1999. They evaluate forecasts on an out-of-sample basis, estimating the model for one part of the sample, and then forecasting crashes in the remaining

¹¹ Tuomas Komulainen, Johanna Lukkarila, "What drives financial crises in emerging markets?", International Conference on Policy Modeling (EcoMod), Istanbul, 2003, p.3.

¹² Ali Ari, "An Early Warning Signals Approach to the Currency Crises: The Turkish Case", 2009, p.13.

sample period. Their model has relatively good forecasting power.¹³

The third step in the construction of an EWS consists in selecting a set of potential crisis determinants. In that sense, one surveys both the theoretical crisis literature and the former empirical studies that put forward some potential key crisis factors. Regardless of the methodology adopted and/or countries and period of the sample selected, some indicators generally emerge as informative and significant in predicting crisis episodes: overvaluations of the domestic currency, high ratios of M2 to foreign exchange reserves, domestic credit growths, high ratios of short-term debt to foreign exchange reserves, and also outbreak of a crisis in another country (contagion). This shows the fact that—as stated in Arias 2003—in order to explain crisis episodes, particularly those that came out in the late 1990s, one needs to combine the determinants underlined in the so-called first, second and third generation crisis models.¹⁴

4. Conclusion: to a new Early Warning System?

The Early Warning System models can be made most useful to help sustain global growth and maintain financial stability, especially in light of the lessons learned from the current and past crises.

But one criticism we often hear about EWS in the past is that the system is often good in replicating the last crisis but is less useful in anticipating future crises. A key reason for this is the way the EWS models have been calibrated to fit the explanation for the last crisis, and hence, becomes less useful for

anticipating future crises when circumstances or the risk factor change.

Therefore, the new EWS to be useful, it must have the ability to anticipate the nature of future crises with certain accuracy. This, of course, is going to be a demanding task, but it is this quality that the EWS process needs to have. This is because without certain degree of accuracy, it will be difficult to persuade policymakers to collectively become engaged in addressing certain risk and vulnerabilities.

The task could be easier achieved if the focus of EWS is narrowed down to the really important systemic issues i.e, the issues that have high-global impact but are beyond the capabilities of market and individual economies to monitor and make assessment. This include the robustness of the key global financial markets and infrastructure, risk relating to the systemically-important large economies and the operations of the internationally-important financial institutions.

The focus of EWS should expand beyond macro-misalignments based on historical relationships to include assessing the robustness and the resiliency of the systemically-important markets, system, and institutions. This means the key objective of EWS will not be to forecast future crises per se, but to identify vulnerabilities in the most important areas in advance, especially those risks that are not covered by market data or by the surveillance process elsewhere.

For EWS to be effective and comprehensive, it should be done at two levels to cover both the global dimension and the country-specific dimension of risk.

The focus of the EWS at the country-level also needs to expand beyond detecting and avoiding local macro-misalignments, and to include assessment of the resiliency and robustness of the domestic economy

¹³ Tuomas Komulainen, Johanna Lukkarila, "What drives financial crises in emerging markets?", International Conference on Policy Modeling (EcoMod), Istanbul, 2003, p.4.

¹⁴ Ali Ari, "An Early Warning Signals Approach to the Currency Crises: The Turkish Case", 2009, p.14.

and financial system to withstand large external shocks. The key point here is that, even with good policies, crisis can happen to an economy if the externally-induced factors overwhelm the abilities and the robustness of the domestic economy to cope with.

The value of early warning is that warning leads to the needed actions being taken in advance. This

means the EWS process should serve to facilitate actions to deal with the important risk and issues by the relevant parties. To serve this end, credibility and effectiveness of the EWS depends on appropriate degree of transparency of the structural models and its appropriateness to the context, whether national or markets, as much as its track record.

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