



## ORIGINAL PAPER

# A Retrospective of Previous Financial Crises Based on a Methodical Analysis of the Inevitable Extreme Events

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### Abstract

The main aim of this paper is to provide a thorough observation for the past financial crises have been enlisted by discussing the past empirical studies with detailed discussion on the strategy adopted, crises covered, methodology implemented and the outcome of the study. For this purpose, most of the studies which are covered have been conducted between the late 1980s to early 2010s. Moreover, the covered studies are of various range that include from non-parametric to parametric, simple statistical to complex mathematical models, and the advanced computerized techniques. Thus this paper is an exhaustive approach to provide the comprehensive knowledge about the crises and the methods undertaken to gain knowledge even for common readers.

**Keywords:** *Financial Crises; Empirical Models; Asian Financial Crises; extreme events; globalization.*

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### **Introduction**

If future crises are assured, then what measures can be taken to at least reduce their frequency and volume? Carrying on that point while speaking about future crises is really important because history gives a readable image of how disastrous these events can be, if they occur. There should be some tools which could provide warning in advance by looking at the market situations that whether the crisis-tsunami is lurking around or the markets are performing properly. For better understanding, the following section has looked at some previous studies and discussed their work, findings and its utility to provide a comprehensive knowledge to the reader about crises which is the central objective of this research study. To deliver an idea, White (1984) analysed the banking crisis of 1930' and concluded that the main contributors for the great depression were the uncontrolled factors which later lead to bank panics and foreclosures of many banks. There were weak regulatory controls which lead the banks into worse positions and it resulted in those closures. White (1984) applied the principal component method using the balance sheet data of banks in a logistic regression framework. The model performed well in highlighting the main causes of the 1930 banking crisis. The main finding was the failure of the Federal Reserve which was unable to maintain a strong growth of money supply and it resulted in tightening of financial markets. The amount of cash available at the Federal Reserve Bank in the form of reserves were clearly better than the investments in peripheral loans or bonds.

Constricted money markets made sure that Bank's sources of funds were becoming costlier, and any bank with inexpensive sources of funds were resilient. All in all, the features of the banks that failed in the 1930 were quite analogous to the ones which broke earlier in 1920's and the banking system received a glimpse of those problems during the subprime crisis but in a different fabric. According to Spulbar & Birau (2019) the global financial crisis in 2008 generated unprecedented dynamic financial contractions.

In a different study, Felice (1997) examined the macroeconomic variables for systemic risk and emphasized that in banking crises, Domino effects always exist, and there is a connection between macroeconomic developments and the financial sector's health. The systemic risk arises when macroeconomic changes get disturbed and lead to credit losses and financial firms' failure because of asymmetric information. This can put the performance of whole financial markets at stake ultimately. Thus, all those macroeconomic variables can be seen as useful indicators to access the position if systemic risk is present among different markets. Frankel & Rose (1996) studied that what are the chief causes of disruptions, especially those which can add to the country's vulnerability to a wreck. The study selected the variables of interest to realize the crashes and classified them into four different categories including; foreign variables, domestic macro-variables, external variables, and the debt composition. Regarding the behavior of financial markets, Pinto et al. (2020) suggested that risk anomalies lead to obtaining the portfolio outperformance of low volatility stocks. The study was non-structural and took the shape of graphical and multivariate statistical analysis.

In the subject field, currency crash was determined as a nominal depreciation of the currency of at least (25%) and there is also an escalation of at least (10%) growth in the pace of depreciation. The data set encompassed the annual observations from 1971 to 1992 for 105 countries. Graphical analysis showed that countries having currency crashes tend to take in higher interest rates, overvalued currency, exceeding levels of

debt, and very low levels of reserves. In short, countries along the brink of crashes bear very weak external conditions. For the probit model, study used 7 debt composition variables, four external variables, and three macroeconomic variables. Most of the results were significant, especially the joint results of the variables. Low fractions of debt, which is either concessional or accounted for by Foreign Direct Investment (FDI) or a higher fraction which is a public sector, they all increase the chance of future crash. Low reserves, overvaluation, high interest rates or high domestic growth, all predict the crisis. Overall the study marks as a very good initial start for the future research on currency crashes.

### **Non-Parametric Investigative Studies**

Kaminsky, Lizondo and Reinhart (1997) introduced a framework for predicting future crises. The study led up an access for early warning systems named as “Signals Approach”. This was also known as the approach of Kaminsky – Lizondo - Reinhart (1997) or as the acronym KLR (1997). It used variables as indicators and signal crisis when a variable cross certain optimum level called a threshold. Granting to the study, five steps should be adopted in order to render a thorough analysis which include; time period, country coverage, variables incorporated, method used, and defining crisis. While inferring to the definition, this approach calls for observing the development of few economic variables. When at least one of these variables departs from its mean value outside an optimum point, this is necessitated as a warning of the possibility of upcoming crisis within a specific point of time. Moreover, the work also defined crisis as a state in which an attack along the currency leads to an acute depreciation of the currency, a larger decline in international reserves or both the situations at once. This definition was broad enough to include crashes under fixed exchange rate as well as under other exchange rate regimes. For each state, the crises were identified through the behaviour of the Exchange Market Pressure Index (EMPI).

The index is a weighted average monthly percentage change in the exchange rate and the monthly percentage change in the gross international reserves, and the weights are chosen in an order so that the components of the index should have the same conditional variance. The index surges with the growth in depreciation of currency and the loss of reserves. Increased EMPI indicates a firm insistence along the domestic currency and highlights the possibility of crashes. According to the study, epochs during which the index surges above its mean by more than three standard deviations, are considered as crises. The choice of variables is purely based on the theoretical considerations and on the availability of information on monthly bases, considering the fact that this empirical study is based on monthly observations.

For all variables except the exchange and interest rates, the study used the 12 month percentage changes of the variables, to ensure the comparability of the units across countries and also to ensure that variables are stationary, have proper moments, and are without any seasonal effects. It is important to mention that interest rate is taken into consideration at levels and exchange rate is used as deviation from trend. Some terms were coined in the study such as signalling horizon. That is the time-period within which the variables are expected to have the capacity to anticipate crises ahead of their actual occurrence. This period was defined as 24-months. The signal horizon is flexible and many other studies have taken a change from 12 months to maximum 24 months. It means that a signal trailed by a crisis within the 24 months of issuing that signal, is

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considered as a “good signal” otherwise it is taken as “noise” if it does signal beyond that period.

Another term which was coined was “signals and threshold” which is; an indicator is said to issue a signal whenever it deviates from its normal value beyond a certain optimum level, that is, a level chosen to assure that the variable is in adverse situation. The level was chosen in a way to strike a balance between the risk of having many false signals and missing of many good signals. Moreover, the thresholds were defined in relation to the percentiles of the distribution of observations of the indicators. The relationship between issuing and missing good and bad signals can better be explained with the help of the following matrix.

**Table no.1: Matrix of Crisis Signals**

	<b>Crisis (within 24 Months)</b>	<b>No-Crisis (within 24 Months)</b>
Signal was issued	A	B
No-Signal was issued	C	D

Source: Authors’ own calculations

A indicates that a signal was issued and there is an actual crisis within 24 months, while D did not signal a crisis for 24 months and during that time no actual crisis occurred. Therefore, A and D are considered to be good signals, whereas B and C are the false alarms as in case of B no crisis happened within 24 months, but a signal was issued and on the other hand, in C, a signal was issued but no crisis occurred within 24 months. If a variable issues signal within a given time period, this signal is coded on a binary scale and given the value one, and the variable takes the value as zero if it does not signal within the given time horizon. Furthermore, the indicators are selected based on their performance of Noise to Signal Ratio (NTSR) which is the ratio of the bad signals to total bad signals issued, to the ratio of good signals issued to the total number of good signals i.e.  $(B/B+D) / (A/A+C)$ . The variables with smallest values in terms of noise to signal ratio are considered as best and more accurate variables, and based on the information from NTSR, it can be used as criteria to decide that which variables to keep and which ones to eliminate from the set of possible variables. So, in order for the variable to be in the model, its NTSR should be less than unity, which means the variable should issue more good signals compared to the noise. Based on theoretical consideration and availability of information, the study used 15 variables. The sample variables are the following: 1-international reserves, 2-Imports, 3-Exports, 4-Terms of Trade, 5-Deviation of the real exchange from trend, 6-Difference between domestic and foreign interest rate (IR Differential), 7-Excess real M1 balances, 8-M2, 9-Domestic credit/GDP, 10-Real interest rate, 11-Lending/Deposit rate, 12-Bank Deposits, 13-M2 International reserves, 14-Output, 15-Equity Prices.

KLR (1997) work proved that signals approach can be useful as the basis for an Early Warning System (EWS) both for currency and banking crises, and the effective early warning system should take into consideration a variety of indicators, as such crises are generally headed by indications that ascend in a number of areas and sectors. Therefore, in order to have a complete and thorough observation, there must be variables from all diversified fields. This study on EWS through signals approach has

revolutionized the literature as it did add up into the few statistical models to be used as EWS. Moreover, this approach has been extensively used, replicated and extended in many ways and provided good bases to look at the vulnerability of the markets and to predict the future crises. Few of the studies which utilized this approach for further investigation and which are discussed subsequently include; Kaminsky & Reinhart (1999); Kaminsky (1999); Zhuang & Dowling (2002); Edison (2003); Oka (2003); Abiad (2003); Lestano, Jacobs, & Kuper (2003); Schlink & Huen (2004); Ciarlone & Trebeschi (2005); Klien & Shabbir (2006); Beckmann, Menkhoff, & Sawischlewski (2008); Lundstrom & Tiberghien (2010); Yum (2012); Cocriş, Percic & Apostoae (2013).

On the other hand, irrespective of its extensive use in literature, this approach has been criticized in the literature due to its few limitations. The definition of crisis is based on the threshold value which is arbitrarily selected, and for variables, in order to get better signals; it is adjusted in a way so that more and more signals should be received while reducing the noise so that a lower value of NTSR can be achieved. This is the drawback of the approach as sometimes the model can work fine, but the results can be misleading. Kaminsky & Reinhart (1999) studied the currency and banking crisis together and coined a term “twin crises” which refers to both currency and banking crisis if they are occurring together. In order to analyse both crises, the study took 20 countries for the period of Jan 1970 to June 1995 and recorded an overall 26 banking crises and 76 currency crises which include 19 episodes as twin crises. With the use of signals approach with threshold ranging from 10% to a maximum 30% of the distribution and crisis window as 24 months prior to the crisis, then used the noise-to-signal ratio as an adjustment criterion to settle for the best fit. Although, their procedure to capture the disturbances during the crises worked well, however, it was not without some limitations pertaining to the framework, as if an indicator gives a signal and this signal is treated as crisis when it is actually a noise, this signal is penalized with high noise-to-signal-ratio, but on the other hand, if an indicator issued a signal within the signalling window and is a good signal, it is just treated as a normal good signal irrespective of the fact that whether the signal was issued 12 or 20 months before the crisis. Overall the model performed very well and the study successfully predicted all the significant episodes of crisis.

Kaminsky (1999) also studied the Asian financial crisis by applying the signals approach of Kaminsky, Lizondo and Reinhart (1997) or KLR framework with the addition of four composite indices to help predict the probability of crises. The study used 24-month window with the same setup as KLR approach designed in 1997. The four composite indicators helped in correcting for some of the drawbacks of the methodology, for example, earlier if a variable issued a signal, it will take the value of “1” no matter if it was a mild or an extreme signal, but the second composite indicator adjusted for this problem and according to it, if a variable issued an extreme signal, then it will be given the weight twice as of the weight to a mild signal. An extreme signal is a quite higher in level than normal signal (way beyond threshold). The probability of the crisis is then calculated with the following formula using all composite indicators.

$$P(C_{t,t+h} | I_t^k < I_t^k < I_j^k) = \frac{\text{month with } I_t^k < I_t^k < I_j^k \text{ and crisis within "h" months}}{\text{month with } I_t^k < I_t^k < I_j^k}$$

Here ‘P’ denotes probability,  $C_{t,t+h}$  is the occurrence of crisis in the interval  $[t, t+h]$ ,  $K = 1, 2, 3, 4$  and  $i, t$  and  $j$  stand for composite indices. The results obtained from

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the model by the use of macroeconomic data were satisfactory, however an argument was made that balance sheet data of financial institutions can even further improve the results. The study focused on the fundamentals of the domestic economy, assessing that how much the near countries are prone to the crises, can even be to extra advantage. As a result, regional and cross regional study seemed more ideal to capture more facts.

Edison (2003) replicated the signals approach. The exchange market pressure index included two instead of three variables which are nominal exchange rate and percentage change in the reserves. Moreover, the pressure index signals crisis when its value goes beyond 2.5 times the standard deviation from its mean and also applied 1.5 standard deviation later. The results showed inconsistency even when repeating the same data set and countries under observation. The maximum probability of crisis was 50%, which means five out of ten crises could correctly be called, which was low, but in accordance with the overall results of the early warning system. One of the explanation which was provided was that indicators keep on issuing signals which lowers the probability because of penalization process. Another explanation was that the studies take the period following the crisis as tranquil periods, but macroeconomic adjustments take time as the economy return to the normal level.

Zhuang & Dowling (2002) replicated the signals approach in a more sophisticated way and investigated that, among weak fundamentals and panic attacks, which hypothesis stands for the Asian financial crisis. The methodology was considered into five basic steps which were; identification of the crisis episodes, selection of the leading indicators, setting up the threshold, constructing the composite leading indicators, and finally predicting the crises. The study used monthly data from June 1970 to June 1995 for five Asian countries and used 25 variables from different sectors. The variables were selected based on their noise-to-signal ratio. The variables with low noise-to-signal ratio were prioritized and kept in the model. Further, the composite leading index was constructed based on variable' issued signals throughout the period to its noise-to-signal ratio, and it was then applied to calculate the probability of the crisis. The model performed well and results indicated that there were clear signs of vulnerability in the economies and weak fundamental were even present long before the crisis which supports the hypothesis that crisis were caused by weak fundamentals.

In a study, based on the debts to the International Monetary Fund (IMF), Oka (2003) predicted crises episodes through the modification of signals approach and the probit-model. The study defined the window for a country to be called under arrears or debts if a country is in continuous debts to the IMF for at least six-months, including at least three months of a particular year. The study not only served the purpose of predicting the debts to the IMF but also tested the reliability of EWS technique and its performance. In the study, signals approach was criticized by stressing that this approach is not reliable due to its raw method of selecting variables based on noise-to-signal ratio, which in itself, is not that dependable. Moreover, performance of probit modelling was also challenged by emphasizing that probit approach carries a drawback that it does not give information pertaining to a particular variable, instead, it provides the information based on the whole group. Largely, the results of the study were satisfactory and it did predict the episodes in which the incidence of debts of a country to the IMF could result in a crisis.

Based on the survey carried out by Abiad (2003), it was emphasized that EWS can be studied conveniently by applying limited dependent variable and signals approach together. However, EWS are always criticized for its numerous familiar

associated methodological concerns. Amongst the most noteworthy issue, is that, they involve a priori dating of crisis incidents before they can be assessed. The most shared way of dating the period is through the application of Exchange Market Pressure Index (EMPI) which takes exchange rates, reserves and sometimes interest rate variables to map the crises based on the sample dependent threshold and recognizing that whether the index crossed the specified limit or not. The drawback which can be highlighted in this criterion is that if the same procedure is applied at a different starting point, it will result in different periods being identified as crises.

The other problem associated with the EWS approaches, lies in the crisis-identification threshold. Because this threshold is selected arbitrary, in literature, there is a range of thresholds deviating from its mean by 1 standard deviation to up to a maximum 3 standard deviations including 1.5, 2, and 2.5 standard deviation. As a result, choosing a different standard deviation most probably bring different dates of crisis and dissimilar values of the coefficients. In addition to that, the threshold is adjusted mostly in a way to maximize the goodness of fit of the model.

The other problem which can incur is that the sample relying nature of the threshold classification, points out that future data may have the ability and may disturb the identification of past crises. The occurrence of large events such as main crises can make the previous episodes which are identified as crises into non crisis, given the fact that threshold is based on the standard deviation of the sample. In the case of dependent variables approach, exclusion window is also another issue which creates an artificial serial correlation and varies from study to study. Moreover, an exclusion window is a time-period which skips any crises identified by the threshold method if they follow a previous crisis within specified event of time. The major motivation behind using the exclusion window is to exclude the identifying speculative pressure periods as new crises, if they are just extensions of preceding ones, but it results in loss of information which may have been available during that time period. Additionally, there is also a loss of information while transforming a continuous variable into binary variable. The same happens in the signals approach in which the explanatory variables are themselves being converted into binary signals.

One significant point to raise here is that although none of the model is perfect for all tasks, but each one has its own strengths and weaknesses and the awareness of the advantages and disadvantages of each model is required in order to pick the right one for a specific task.

While criticizing on those traditional approaches as an EWS, Abiad (2003) proposed an alternative approach as Markov's regime switching model and emphasized that instead of sticking to the orthodox approaches, it is always advantageous to incorporate a new variety of models. Another replication for the KLR approach framed in 1997 was carried out by Schlink & Huen (2004) as a special case to study the crisis situation in Uganda and found that the model was somehow successful in capturing the crisis situations in Uganda and some variables performed well. The study used the same set of variables and transformation treatment as of KLR approach in 1997. The NTSR suggested that real exchange rate performed better than any of the other variables under consideration. Furthermore, the study suggested that contagion variables can be helpful in assessing the crisis situations and its probability and therefore, should be incorporated in the model, seconding the idea of Bussiere & Fratzscher (2002).

Another detailed study based on the EWS was accomplished by Klien & Shabbir (2006). The study analysed the standard approaches used in EWSs. Moreover,

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as a comparative measure to the standard approaches, study demonstrated that the Markov switching model works very well and in the case of the Asian crisis, the model may have predicted the financial turbulences better because it captured the volatility episodes very well. Furthermore, the study sets the guidelines that for an EWS that one must be aware of the country/regional situation (sample under consideration) and also should carefully select that which model need to be adopted, what variables to be used in order to make correct crisis predictions because the after effects for crisis are huge on society and it can be economically very costly if the predictions go wrong.

Ciarlone & Trebeschi (2005) designed an EWS for debt crises and defined debt crisis based on a broader definition of debt crises and devised that the crisis is called if any of the given criteria matches to the situation. Logit regression model was applied to the dataset which comprised of 28 macroeconomic variables dating from 1980 to 2001 on annual basis including 616 observations. The model was estimated through three different steps. As a first step, the logit regression for each of the 28 variables was carried out one by one and the insignificant variables or the variables with negative signs were removed. In the second step, the significant variables in first step were formed into different groups from the same family and model was re-estimated and again the significant variables with correct signs were kept. As a last step, all the significant variables from second step were put together into a general regression model and all the variables which were significant in the final equation were taken as important variables for a debt crisis. The model performed well and correctly called (76%) of observations in the multinomial model and (77%) of observations in binomial model. Furthermore, the argument was made that EWS works unsurpassed when there is timely information on relevant macroeconomic situations in the form of accurate data, an argument which was later supported by Fuertes & Kalotychou (2007).

Beckmann, Menkhoff, & Sawischlewski (2008) also studied the EWS and operated all the traditional approaches including bivariate and multivariate logit models. Study results suggested that logit models perform better than non-parametric approaches, but on the other hand, criticized multinomial logit models as according to the study, the results between the binomial and multinomial were not much different but treatment for binomial is easy and it is also easy to handle. Moreover, it was suggested that the use of regional framework and contagion variable is a necessary part of the EWS because according to the study, contagion is mostly present among financial markets. Lundstrom & Tiberg (2010) studied the banking crisis and the probability of bank run in Greece with the help of signals approach. The replication of the KLR (1997) was performed for the period of 2002 to 2009 using 14 of the 16 variables used in the original study and followed the same transformation mechanism for variables and used NTSR as decision criteria for variable' performance. The results indicated that the probability for banking and currency crisis captured was very low, suggesting that there is a need to make some adjustments in model specification or on how the crises have been defined. Yum (2012) applied both the logit model and signals approach to investigate the behaviour of economic and financial variables during Asian financial crisis and concluded that both the approaches performed well and many relevant variables were proved to be significant during the crisis time period suggesting that EWS can work well if adopted properly.



### **Parametric Investigative Studies**

Eichengreen & Rose (1998) argued that the currency crises cannot be simply identified with changes only in the exchange rate regime, as not all decisions to devalue or float their exchange rate are preceded by speculative attacks. As a result, they measured the speculative pressure using a weighted average of variations in the exchange rates, interest rates and the reserves. All the variables were tested relative to the one of core country (US). When there is a speculative attack on the currency, it can lead to three possible situations, pressure may cause a loss of reserves, or it can be compensated through an increase in interest rate, or may occurred through depreciation or even the devaluation of the exchange rate. On this argument, the study analysed the experience of 20 OECD countries, using data which cover up to 1950's. The main finding of the study was that the devaluations which highlights currency crises usually happened after the periods of high expansionary, monetary, and fiscal policies. This may cause in wage and price inflation, weakening international competitiveness and worsening of external accounts. Moreover, when the devaluation befalls, it is complemented with some monetary and fiscal cutbacks to reassure investors and to make the new levels of exchange rate sustainable. Results indicated and supported that mostly the speculative attacks unfold contrarily in situations of high and low capital movement and confirmed that the capital controls presence make the devaluations unlikely and surges the viewpoint that speculative attack will be better resisted by the government. The study suggested that, capital controls are endogenous and there are more chances that they occur after the exchange rate has been devalued and vanish soon after there is a failed attempt. The study also pointed to the presence of contagion during the Asian financial crisis. Overall, the study focused on banking crises episodes as well as shed light on some of the misleading indicators suggesting that sometimes variables can provide some spurious results.

Chang & Velasco (1998) focused on the Asian financial crisis to study why there was no crisis in Latin America during the Asian turmoil. The study compared the macro-economic fundamentals of both regions and concluded that although Asian markets were doing well before the crisis, but their fundamental positions were not strong and there were clear signs of distress before the crisis erupt. International illiquidity in Asian markets put the nail in the coffin. Moreover, as most of the symptoms present in Asian markets were absent in Latin America, therefore those markets were buffered from the crisis. In addition, Berg & Pattillo (1999, 2000) studied the early warning systems and its importance with regards to crises predictions. The study argued that the economic and financial market system has become more complex and in order to have a fair look at the market, the system should consider all the possible areas of risk with the help of indicators, especially the fundamentals and vulnerability indicators. Moreover, according to the study, predicting the exact timing of crisis is almost impossible, however, a model can predict the relative severity of the upcoming crisis with the help of the indicators and such models can be useful in identifying which countries are more vulnerable to crisis instead of predicting their timings. The study claimed further that, although early warning systems are not perfect, but because of their beforehand cautions, at least they can add to the decisions of policy-makers to be vigilant.

Lau & Yan (2005) used nested logit model to predict financial crises. In the study, a detailed discussion on available models and approaches to predict the crises was provided and argument was built that different techniques have different advantages and

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drawbacks and whichever technique to be applied depends purely upon the interest and purpose of the study. Moreover, the study also discussed some important variables pertaining to financial crisis prediction and their performance during the periods of vulnerability. Moreover, the study also analysed the relative importance of various internal and external economic factors in triggering speculative attacks. In the study, signals approach was also used as a comparative measure alongside the nested logit model and the result of the nested logit model outperformed the signals approach in predicting currency crises and the study produced some robust results. A challenging argument based on financial liberalization was also made that it should be accompanied with some supervision and regulation and also it is important to have enough level of reserves to meet any unexpected situation along with better policy implications.

Bussiere & Fratzscher (2002) pioneered a study based on the multinomial logit approach as it brought many significant changes in the multinomial logit models in order for them to be used as an early warning system. In the study, argument was made that the main reason for the inability of early warning system models to capture crises with much accuracy lie mainly in the fact that in such models, usually the pre-crisis and post-crisis periods are treated in the same way but in reality, the behaviour of the markets and the economy itself is completely different during that time as economy goes into the recovery phase which is usually accompanied with very slow growth and comparing it with pre-crisis periods can generate a bias (often referred to as post crisis bias), though a concept which was later criticized by Beckmann, Menkhoff & Sawischlewski (2008). In order to adjust for post-crisis bias, the multinational logit model applied in the study used three proxies, ie pre-crisis, crisis, and post crisis, instead of two as in binomial logit model to capture the post-crisis effects separately. Moreover, in the framework, EMPI was defined based on the three variables which are exchange rate, interest rate, and international reserves similar to the KLR approach in 1997. However, instead of taking the values at nominal level, as in most of the studies, it took the real values for the variables. Using the real values for interest rate and exchange rate accounted for the alterations in inflation rates over time and across countries.

$$EMPI_{i,t} = \omega_{RER} \left[ \frac{RER_{i,t} - RER_{i,t-1}}{RER_{i,t-1}} \right] + \omega_r (r_{i,t} - r_{i,t-1}) - \omega_{RES} \left[ \frac{RES_{i,t} - RES_{i,t-1}}{RES_{i,t} - RES_{i,t-1}} \right]$$

Where  $\omega_{RER}$ ,  $\omega_r$  and  $\omega_{RES}$  are the relative precisions of each variable in order to offer a larger weight to the variables having low volatility. RER stands for exchange rate  $r$  is the interest rate and RES stands for international reserves. Moreover,  $i$  and  $t$  are proxies for a particular country and time period respectively. EMPI signals crisis when its 2 standard deviation above its mean value. The rationale behind using the weighted average of above three variables is that if investors consider the underlying economic factors as unsustainable or vulnerable and there is an attack on the currency, the government has two options, the first one is that either government can refrain from defending the currency. It can be done in two ways, either by abandoning the fixed exchange rate or by avoiding itself to intervene in the foreign exchange market so that the market can decide on the new price after currency is being devalued. Contrary to that, the second option for a country to defend its currency can be through two different ways; In order to maintain the exchange level, a country can increase the interest rate, or

it can exhaust its international reserves. EMPI has the characteristic to capture both of the options adopted by the government. In line to the idea of Berg & Pattillo (2000), the study agreed that predicting crises with exact timing is not possible, as a result, it focused on predicting a crisis within some specific time-period. The study used monthly data observations from the period December 1993 to September 2001 for a sample of 32 countries, with the assumption that all countries share common characteristics in terms of openness to capital flows. 27 variables were tested in total, out of which only 6 variables were kept in the final model and an additional dummy variable was also added to test for the presence of contagion. The results of Bussiere & Fratzscher (2002) indicated that the multinomial logit model performed better than the binomial logit model and moving from binomial to multinomial logit improved the prediction of crises and reduced the number of false alarms. In addition to that, the contagion variable showed significance, indicating that crises are not usually isolated, but rather are interconnected events across economies. Moreover, the model did capture the asymmetric behaviour of the investors. After the crisis, if the situations become normal again, it takes longer for investors to come back than to leave when panic fuel the markets, resulting in a left skewed shape of EMPI.

#### **Other Mixed Research Studies**

The use of Artificial Neural Network (ANN) as an EWS was carried out by Nag & Mitra (1999) for currency crises, and performance of the indicator approach across Malaysia, Indonesia and Thailand was compared based on monthly data from Jan-1980 to Jan-1998. Although neural networks have some advantages such as their ability to capture complex interactions among variables, but this flexibility can even be misleading and a drawback is the danger of over fitting which becomes much higher than commonly adopted EWS methodologies. There are no coefficient estimates, and the interactions among the variables can be complicated, which makes it difficult to determine which indicators have abnormal behaviour and driving the forecast probabilities. The study was adopted based on country by country analysis of the KLR (1997) approach by replicating 16 variables out of the 24 variables and it was realized that different variables were significant for different countries. Interestingly, the study did not find the real exchange rate as a significant variable which was quite unexpected.

Vlaar (2000) used the continuous crisis index itself as a warning system instead of adopting a binary crisis dummy variable. The study modelled the crisis index, which was drawn from a mixture of two normal distributions. The mean and variance of each distribution was modelled as a function of various indicators, as is the relative weighting of the two distributions. The model successfully predicted 7 out of 8 crises for both selected period and the out-of-sample predicted period. However, the study issued fair amount of false signals as well. Latent Variable Threshold Model (LVTM) was used by Collins (2003) for analysing the timing of the crises. The model assumed that the crisis occurred because of some unobservable factors reach to certain threshold levels. The study used a latent variable which has Brownian motion with drift. The probability of occurrence of crisis had an inverse Gaussian distribution conditional on the drift factor, the distance to the threshold and the variance of the Brownian motion. The distance and drift factors were modelled as linear functions of the five standard indicators. The study did a model test against Probit and Poisson models and found that the adopted model fits better than any of the comparable models.

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Burkart & Coudert (2002) adopted Fisher Discriminant Analysis (FDA) to study the currency crises. This method classified dependent variable into one of 'k' given states, based on information from a set of predictor variables. The main focus was to determine whether the 'k' states differ with regards to the mean of a variable. This model was then used to construct predictions for the states. Results suggested that the discriminant model based on studied indicators performed quite well. Zhang (2001) used Autoregressive Conditional Hazard (ACH) model as a main model and both ACH and probit models were estimated to study crises and results underlined that ACH fit the data better than the complementary model. However, as the adopted models were not nested, therefore, the comparison did not carry much significance.

Ghosh & Ghosh (2003) used Binary Recursive Tree (BRT) to analyse the influences of different variables onto each other. Firstly, the thresholds for each indicator were identified that minimize the false signals and encourage the good signals. Then the sample split into two branches applying the threshold from the best indicator. That means the indicator with maximum number of good signals. These processes continued to construct sub-branches until a stopping rule matches. Using this strategy, the study captured some interactions among the variables which were not easily captured using standard probit models to investigate crises. Gabel (2003) critically examined the efforts of the researchers and economists (especially after the European, Mexican, and Asian Currency Crises) on the theoretical and empirical grounds. The study argued that the predictor techniques adopted by researchers, performed poorly in empirical framework for such crises. Indeed, the techniques developed after each crisis failed badly to predict the next major crisis. These techniques were also not well justified on theoretical grounds. According to the study, there are many predictor indicators which are in line with the post-Keynesian economic theory, but they do not present any solid means to prevent the crises. The study concluded that regime in which "trip wires" and "speed bumps" operate, help in stabilizing the economy though growth can be slow.

In the study based on early warning systems in six Asian countries, Lestano, Jacobs, & Kuper (2003) examined the predictive ability of the indicators to anticipate the crises. For a better explanation and understanding, the study sheds light on the previous EWS methods used frequently in the literature. The study adopted the methodology of Frankel & Rose (1995); Eichengreen, Rose, & Wyplosz (1995); Kaminsky, Lizondo and Reinhart (1997); Frankel & Rose (1996); and Zhang (2001) for the mapping of currency crises. All of the models applied in the studies had their own way of defining the crises. In the study, four groups of indicators were extracted and then applied to multivariate logit model in a panel of six Asian countries for the period of 1970 to 2001 using monthly observations. The study incorporated 26 variable indicators and grouped identical indicators together with the help of factor analysis. These factors then were used as explanatory variables in that panel framework. The overall analysis indicated that different approaches provided different results for the crises dates which exploit the dependence of these models on different parameters and highlighted that most of the models are even sensitive to a small change in how you define those parameters.

The financial crisis of 1996 - 1997 in Bulgaria was studied by Feridun (2006) who replicated to the Frankel & Rose (1996) methodology. The logit model included 26 macroeconomic, political, and financial sector variables for the period of 1981 to 1997 on monthly observations. Only six of the 26 variables proved to be significant. Moreover, it was argued that the crisis somehow can be explained with the help of three generation models which have the ability to capture almost all the disruptions present in

the market thus complementing the role of generation models. Li, Rajan, & Willett (2006) studied the currency crises with the help of EMPI indices and argued that most of the studies take exchange rates, reserves and interest rates to formulate the EMPI and use the ratio of the inverse of the variance of the variables as a weight which, according to the study, does not have any valid economic interpretation as it results from a combination of market generated volatilities and policy reaction functions. It can even generate downward biases in case of unsuccessful attacks. The study suggested further that even if there are no good estimates available for samples, then the alternative approach should be to use the principle of equal ignorance and equal weights should be applied.

Davis & Karim (2008) studied the banking crises in 105 countries for the time period of 1979 to 2003 using annual observations. The study applied both logit model and signals approach and defined that banking crises could only exist if any of the four conditions meet the criteria. These four conditions are the following:

1. The proportion of non-performing loans to total banking system assets exceeded 10%.
2. Public bailout cost exceeded 2% of GDP.
3. Systematic crisis caused large scale bank nationalization.
4. Extensive bank runs were visible or if not, emergency government intervention was visible.

For the logit framework, the study followed the Demirguc-Kunt & Detragiache (1998) approach and extended the model, countries (such as Hong-Kong, South Africa), and time span (1979-2003). Results indicated that the multinomial logit model is better suited approach when looking into global EWS, whereas, the signal extraction approach works better to country-specific EWS, in line to the idea of Edison (2003) and further argued that a generalized global model cannot replace the country specific studies. A different EWS technique using the Stock Market Instability Index (SMII) was proposed by Kim, Lee, Oh, & Kim (2009). In the approach, it was argued that Instability Oriented Approach (IOA) is appealing and popular, but usually the instability period is short lived compared to the stable period, therefore, it is difficult to find large data on that. As a solution, the study proposed a new term, Stability Oriented Approach (SOA) which focuses on how the current stock market situations differ from ordinary stable market conditions. As a result, SOA was developed into a SMII through statistical training of an artificial neural network to the base period and in calculating discrepancies between the observed and the expected values of the trained ANN (Kim, Lee, Oh, & Kim, 2009). The study applied the SMII approach to Korean stock market for the period of January 1993 to January 2003 and observed that there were clear turbulent symptoms and the AFC 1997 impact could clearly be realized.

Ege & Bayrakdaroglu (2010) conducted a special study on financial crises in Turkey with the help of pressure indices. In order to observe the crises episodes, the study applied different pressure indices, based on previous studies, for the time period of January 1990 to December 2009 taking monthly observations. The results suggested that the indices cannot always give a warning of a crisis and some even failed to predict crises, indicating that it is not worthy to decide on the basis of indices and the financial indicators that an economy is away from the crises as crises can also be the result of the interaction among social events, political conflicts, and many other significant factors. To elaborate further, it was addressed that a single index may not be sufficient to predict

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all crises and it is also irrational to believe that a model which has predicted one crisis will be able to predict the next crisis for granted.

### **Conclusions**

There have been many investigative studies in the literature on crises and after having all the above discussion and criticism of selected studies, it is noteworthy to realize that there is no solid platform on which one could predict an economic or financial crisis accurately under all berths before it happens. It demonstrates the complexity of the current financial markets and the weakness of the system for not bearing a strong framework to predict the disruptions beforehand and to be pro-active instead of being responsive. Financial vulnerability has significantly been increased after the financial liberalization, but one cannot merely blame on the liberalization as it equally has many advantages and overall it has a positive impact on the financial markets as agreed by Stulz, (2005); Kose, Prasaad, Rogoff, & Wei, (2006); Moshirian, (2008). The inquiry which then comes into judgment is how to dispense with the vulnerable situations with minimum impairment and what are the tools which can furnish the best support to tackle with those situations. When explaining specifically about the EWSs, it is for common understanding that there are bundle of approaches available to study and examine the market positions, but unfortunately it is difficult to determine that which approach is the best as crises vary from time to time and situation to situation. The ideal way to select the best approach is through understanding of the marketplace and the major elements or factors which can play a big role in the vulnerability. Only then there is a chance to pick the appropriate tools along with selecting suitable indicators to examine the situation and implementation of suitable strategies. We do not have one-fit-for-all or tailor made solutions.

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