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# CONTENTS

# A Narrative Literature Review of Signal Approach as a Method of Early Warning System

Dr. Doa Naqvi* and Rahat Zabi**

## ABSTRACT

The world has experienced covid-19 as largest economic shock in this decade. There is uncertainty about the impact of coronavirus pandemic on economic activities, people lives and livelihood and there are many countries facing multiple crises such as- financial crisis and health crisis. For the identification of impending financial crisis, there are various early warning systems such as signal approach, Logit/Probit Model, and Neural Network Model etc.

This study examines the conceptual domain of signal approach of early warning system. Kaminskey- Lizondo-Reinhart (KLR) signal approach monitors the economic indicators such as terms of trade, foreign exchange reserve, real interest rate, foreign direct investment, imports, exports, current account balance etc. which reveal unusual behaviour prior to an economic crisis. Divergence of indicators from their threshold value has been interpreted as a warning signal, as per previous literature. Signal approach works effectively when there are sharp changes between crisis periods and periods of tranquility. With the objective to clarify the concept of signal approach and development of historical literature over a period, this study evaluates research articles related to signal approach, which have been published between 1998 to 2019. This study will help academicians, researchers and professionals in understanding the mechanism of KLR (Signal approach) and create useful information for economic policy makers to anticipate signals of economic crisis.

***Keywords:*** Early warning system, Financial crisis, Currency crisis, Banking crisis, Signal approach, Noise to signal ratio, and Threshold value.

## INTRODUCTION

*"When you're in a crisis of, you know, tremendous proportions, its beyond any human capability to control, you just make the best decisions you can, and you just hope that your institution is correct."* Rudy Giuliani (Ozili, 2020)

In the history of world economy, many crises have been recorded, such as tulip mania episode around 1636, stock market crash 1929, European countries crisis (currency crisis)1992, Mexico crisis 1994, South East Asian currency crisis 1997, Russian financial crisis, Latin America crisis 1998, Argentina great depression 1998-2002, subprime crisis 2008 and recent crisis in emerging countries and advanced countries.

A diversity of turmoil and economic mechanism can be grouped under the name of financial crises (Dumitrescu, 2012). There are mainly three types of financial crises, i.e. currency crises, banking crises, and sovereign debt crises (Kaminskey, Lizondo, & Reinhart, 1998). Currency crisis has been

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defined as a situation in which value of country's currency depreciates rapidly or declines unexpectedly in foreign exchange reserve or combination of both or due to speculative attack on currency sharp increment in domestic interest rates takes place (Balaga & Padhi, 2017). Further, Banking crisis- is a situation in which bank runs lead to closure, merger or takeover of banks. (Goldstein, Kamisnky, & Reinhart, 2010). In the study of Dawood (2016) banking crisis is defined as bank runs, mergers, takeovers and closure of large banks or finanacial institutions, decrement in banking capital, massive intervention of government in banking sector, increment in ratio of non-performing loans to total bank assets. Soverign debt is a crisis in which a country facing debt crisis, is rated by Standard & Poor rating agency as being in default, or if a country takes loan from IMF finance department in excess of 100% of its quota. (Manasse *et al*., 2003). Due to financial crisis countries faces many problems such as: losses in foreign exchange reserve, reduction in output, worsening standard of living, increment of non-performing assets due to credit crunch etc. (Dawood, 2016).

Historical evidence shows that financial crises continues to occur unobserved and affects many countries greatly in spite of different early warning models proposed (Dumitrescu, 2012). Early warning systems are the mechanism that monitor, examine and transform information held by financial indicators in the signals related to possibility of crisis (Ionela, 2014). It is used to predict upcoming financial crises. It means that EWS is an alarming system which aims to observe the macroeconomic indicators of economy and give the signal when they reach beyond the threshold value.

One of the early warning system models is signaling approach in which the value of macroeconomic indicators is translated in binary signals for forthcoming crises. A crisis is signalled when the value of macroeconomic indicators crosses the threshold value (Bryde- Erichesn, 2016).

The signal approach was developed by Kaminskey, Lizondo, and Reinhart (KLR, 1998), Kamisnkey, Reinhart (1999), Kaminskey (1999), Goldstein, Kaminskey, Reinhart (2000) (Roy, 2009 ).

The signal approach has long history in literature but recently it has been applied to examine the financial crises. It works effectively when there are sharp changes in period of crises and periods of tranquility. It is a nonparametric approach which focuses on high frequency of data, facilitating deeper understanding of changes in macroeconomic trends that leads a country into crises (Roy, 2009). Many international financial institutions and central banks being used early warning systems for monitoring their activities. The International Monetary Fund maintain two EWS models first one is Developing Countries Studies Division (DCSD) based on multivariate probit regression and second one is KLR model based on Signal approach (Roy, 2009). Early warning system plays a vital role in defining economic policies on an international, macro or micro level.

In this study, we focus to answer the question "How signal approach is used as an early warning system in earlier research?" This paper explores the concept of signal approach of early warning system. The analysis of literature review presents a progressive picture of research in relation to this particular topic. The objectives of the research are to evaluate the concepts, techniques and mechanisms that have been used in germane literature to study the early warning systems. The paper is presented in the following manner. Section 2 is related to literature review, Section 3 methodology of signal approach, Section 4 is analysis of literature review, Section 4 discusses about the results and section 5 gives the conclusion.

## REVIEW OF LITERATURE

There is no exact definition of financial crisis but increase in the number of crisis and importance of their impact on the economy has generated large amount of research on early warning systems. EWS is a system which is used to monitor, investigate and give information about upcoming financial crisis (Ionela, 2014). One of the early warning models is Signal approach. This approach was adopted for the prediction of currency crisis by the Kaminskey, Lizondo, and Reinhart in 1998.

We conducted a narrative literature review for the comprehension of the concept of signal approach. According to Green et.al (2006) Narrative literature reviews are three types: commentaries, editorials and overview articles. Our paper is based on narrative overviews which is also known as unsystematic narrative reviews. Narrative overview is the summarisation of the content of a particular topic and it also provides broad prospects and stimulates the thoughts related to the topic (Green, Johnson, & Adams, 2006)

So, we have selected the some referred journals from 1998 to 2019 on the basis of the following key words such as early warning system, signal approach, financial crisis, and currency crisis. The lists of the journals are given below:

| Title | Authors | Year | Database | journals |
|---|---|---|---|---|
| "Leading indicators of currency crisis" | Graciela Kaminsky, Saul Lizondo, Carmen M. Reinhart | 1998 | JSTOR | Palgrave Macmillan |
| "Are currency crisis predictable? A test" | Andrew Berg, Catherine Pattillo | 1999 | JSTOR | Palgrave Macmillan |
| Predicting currency crises: The indicators approach and an alternative | Andrew Berg, Catherine Pattillo | 1999 | ScienceDirect | Journal of International Money and Finance |
| "Neural Network and early warning indicators of currency crisis" | Ashok. K. Nag, Amit Mitra | 1999 | RBI | Reserve Bank of India Occasional Papers |
| "A Review of the Literature on Early Warning Systems for Banking Crises" | Alejandro Gaytan, Christian A. Johnson | 2002 | Central Bank of Chile | Central Bank of Chile Working Papers |
| Do Indicators of Financial Crises Work? An Evaluation of Early Warning System | Hali. J Edison | 2003 | SSRN | International Journal of Finance and Economics |
| "A study on the Early Warning Indicators of Currency Crisis: A regional Perspective" | In Soo Kang | 2004 | Sage | International Area Studies Review |
| "Towards a new early warning system of financial crises" | Matthieu Bussiere, Marcel Fratzscher | 2006 | ScienceDirect | Journal of International Money and Finance |
| "China's Vulnerability to Currency crisis: A KLR signals approach" | Duan Peng, Claustre Bajona | 2008 | ScienceDirect | China Economic Review |
| Forecasting Currency Crises: Which Methods Signaled the South African Crisis of June 2006? | Tobias Knedlik, Rolf Scheufele | 2008 | SSRN | South African Journal of Economics |

| Title | Authors | Year | Database | journals |
|---|---|---|---|---|
| "Early warning systems - anticipation's factors of banking crises" | Strachinaru Adina Ionela | 2014 | ScienceDirect | Procedia Economics and Finance |
| Assessing Indicators of Currency Crisis in Ethiopia: Signals Approach | Kelbesa Megersa and Danny Cassimon (Megersa & Cassimon, 2015) | 2015 | Wiley Online Library | African Development Review |
| "Early warning system of finance stress for India" | Anuradha Guru | 2016 | Routledge Taylor & Francis group | International Review of Applied Economics |
| "Identifying the early warnings of currency crisis in India" | Mohana Rao Balaga, Puja Padhi | 2019 | Sage | Foreign Trade Review |
| "Early Warning Systems for Currency Crises with Real- Time Data" | Tjeerd M. Boonman, Jan P. A. M. Jacobs, Gerard H. Kuper, Alberto Romero | 2019 | Springer | Open Economies Review |

## METHODOLOGY OF SIGNAL APPROACH

This paper is based on concept of signal approach. It is a model in which macroeconomic variables give signals about crisis when variables cross their threshold value. The approach involves four pillars (a) Crisis window, (b) Crisis identification, (c) Threshold value, (d) Noise to signal ratio.

(a) **Crisis window**- Crisis window is also known as signalling horizon is the period in which the behaviour of indicators give signal about the crisis to be happen. Crisis window may be 24, 18, 12 or 6 months according to the data and country specific factors (Roy, 2009).

(b) **Crisis identification**- For the identification of currency crisis, firstly construct an index such as for currency crisis exchange market pressure index (EMPI) (Balaga & Padhi, 2019). EMPI is constructed on the basis of monthly data of weighted average of exchange rates, foreign exchange reserve and interest rate (Roy, 2009).

$$I = \frac{\Delta E}{E} - \frac{\sigma_e}{\sigma_r} \frac{\Delta R}{R}$$

EMPI equation involves percentage change in exchange rates $\frac{\Delta E}{E}$, percentage change in foreign reserves $\frac{\Delta R}{R}$, and ratio of standard deviation of percentage change in exchange rate and reserve $\frac{\sigma_e}{\sigma_r}$.

$$\text{Crisis} = 1, \text{ if } I > \mu_I + m\sigma_I$$
$$\text{Crisis} = 0, \text{ if } I \leq \mu_I + m\sigma_I$$

$\mu_1$ = Mean of EMPI, $\sigma_1$ = Standard deviation of EMPI, ranges from 1.5 to 3 across various studies (Balaga & Padhi, 2017 & 2019).

For identification of banking crisis, Guru (2016) constructed a Banking Sector Stress Index (BSSI). This index is constructed on the basis of ratio of gross non-performing assets to

gross advances of scheduled commercial banks in India (GNPA), Capital to Risk Weighted Assets Ratio (CRAR) and Return on banking sector index of the National Stock Exchange (BIR).

(c) **Optimal threshold value** - It is the value which is calculated on the basis of mean ($\mu_i$), standard deviation, ($\sigma_i$) and median value ($\alpha$) of each economic indicator (Pukeliene & Deksnyte, 2010).

Threshold = $\mu_i \pm \alpha\sigma_i$ (Sevim, Oztekin, Bali, Gumus, & Guresen, 2014).

(d) **Noise to signal ratio (NTSR)**- This ratio gives information about ability of indicators to send a good signal or bad signal. Low value of NTSR shows good signal and high value of NTSR shows bad signal of crisis (Roy, 2009).

Noise to signal ratio is calculated with the help of conditional and unconditional probability. It involves a 2x2 matrix.

|  | Crisis<br>(crisis horizon- 24, 18, or 12 months) | No crisis<br>(crisis horizon- 24, 18, or 12 months) |
|---|---|---|
| Signal was issued | A | B (type II error) |
| No signal was issued | C (type I error) | D |

Source: Kaminskey, Lizondo, & Reinhart, (1998)

Cell A designates the number of months in which indicator issued good signal before an impending crisis.

Cell B represents number of months in which indicators issued bad signals which are in nature of type II error, it means there is absence of crisis.

Cell C represents number of months in which indicators failed to issue signal. It is in nature of type I error.

Cell D represents number of months in which indicator refrained from issuing a bad signal, that is the tranquil months. (Berg & Pattillo,1999).

When indicator issues only good ones and does not miss any crisis within crisis horizon known as 100% perfect signal i.e., A>0 and C= 0 and when the indicator abstain from issuing the signal when there is no crisis and does not issue any wrong signals (noise) i.e., D>0 and B=0 in these cases, the noise to signal ratio is 0. When A=0 and C>0 and D=0 and B>9 noise to signal ratio will be infinity. Conditional probability of crisis is the percentage of good signals can be expressed as $\frac{A}{A+C}$ and percentage of bad signal can be expressed as $\frac{B}{B+D}$. The ratio of percentage of bad signal to percentage good signals is known as noise to signal ratio. It can be expressed as $\frac{\frac{B}{B+D}}{\frac{A}{A+C}}$.

Unconditional probability of currency crisis is expressed as $\frac{A+C}{A+B+C+D}$.

Probability of type I error is $\frac{C}{A+C}$ and probability of type II error is $\frac{B}{B+D}$ (Balaga & Padhi, 2017).

## ANALYSIS OF LITERATURE REVIEW

This review is based on reputed research articles published in journals. The main motive of this analysis of literature review is to explain, evaluate and synthesize relevant facts belonging to signal approach.

| Title | Analysis of Literature Review |
|---|---|
| "Leading indicators of currency crisis" (1998) | This study proposed new early warning system i.e. signal approach for currency crisis. In this study, 15 indicators are used on monthly basis, 24 months have taken as window crisis. There are many variables those give signals for upcoming crisis such as international reserve, real exchange rate, domestic credit, credit to public sector, domestic inflation. |
| "Are currency crisis predictable? A test" (1999) | In this study three methodologies have used for predicting currency crisis for 24 months crisis window post April 1995, 1) KLR approach, 2) probit model, 3) STV model. It involves 17 indicators, out of which 8 indicators gives signal about crisis those are Real exchange rate, M2/reserves growth rate, Export growth rate, International reserves growth rate, Excess M1 balances, Domestic credit/GDP growth rate, Real interest rate, Terms of trade growth rate on the basis of signal approach. According to this study, KLR explanatory power is low, and probit model gives better results in comparison to KLR model. |
| Neural Network and Early Warning indicators of currency crisis (1999) | This study is based on to test the artificial neural network and signal approach for Malaysia, Thailand, Indonesia those were worst victims of East Asian Currency crisis (1997-1998). The Authors find out that Neural Network system gives clear and better signals for upcoming crisis in comparison to signal approach. |
| Towards a new early warning system of financial crises (2006) | This paper proposed new early warning model which is based on multinomial logit model for monitoring the upcoming financial crises. According to this paper signal approach transforms economic variables into binary signal. The transformation of each explanatory variable into binary variables constitutes a significant loss of information in comparison to logit and probit model. |
| Currency crises: Models and their possibility in Lithuania (2010) | In this paper signal approach is used to predict the currency crisis in Lithuania from January 1997 to December 2001. The result of this study is that signal approach works as useful tool for basic diagnosis of currency crisis. It gives six economic variables: current account balance, foreign exchange reserve, interest rates, public foreign reserve, debt, real effective exchange rate, M2 and foreign exchange reserve ratio, those are appropriate for predicting currency crisis in Lithuania. |
| "Early Warning Signal System for Economic Crisis: A threshold and Indicators Approach" (2014) | In this study two models are used: signal approach and probit model as early warning systems for predicting economic crisis in USA, India, and China. It considered six major crises from 1991 to 2011 which include 17 economic variables out of which 13 variables works as informative indicator. According to this study, it is not mandatory that signal approach will be generating good signal it may generate bad signal also. |
| "Identifying the early warnings of currency crisis in India" (2019) | In this study signal extraction methodology and logistic regression model used for identifying currency crisis in India for the period of 1986 to 2015. It includes 17 macroeconomic variables and 12 months crisis window. According to this study, Logit model gives better results in comparison to KLR model in term of goodness of fit measures. |
| Early Warning Systems for Currency Crises with Real-Time Data (2019) | This study is based on to analyse the performance of Signal approach and Logit model for the identification of indicators those give signals for impending crises. It involves 10-15 variables of fifteen emerging countries for the period of 1991 Q1 to 2017 Q4. According to this study, the results of signal approach and Logit model are consistent. |

## RESULTS

This study is based on the conceptual domain of signal approach. We have found that signal approach is used to identify the leading indicators for impending financial crisis, currency crisis and banking crisis. This model monitors the unusual behaviour of indicators prior to a crisis. Signal approach is based on following steps (1) crisis window, (2) identification of crisis, (3) Optimal threshold value and (4) noise to signal ratio. This model is used by many researchers as a tool of early warning system from 1998 to 2019. Mostly authors have found that the capability of predicting the upcoming crises is low in comparison to logit model and Artificial Neural Network.

## CONCLUSION

In the recent period, it is important for the emerging countries as well as advanced countries to find out the early warning system which gives accurate signals for upcoming crises. We have found that signal approach is widely used for the prediction of upcoming crises from 1998 to till now. It helps to find out the leading indicators for upcoming crises and gives signals for impending turmoil. It is not mandatory that leading indicators always give good signals but some time it also give bad signals. The model is useful for the formulation for governmental policies and for central banks of countries. There is ample room for further research to do empirical research of signal approach.

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