Identifying the Early Warnings of Currency Crisis in India

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Abstract

We empirically investigate the recent history of currency crises (stress periods), and the factors influencing their likelihood in India. This study aims at constructing an early warning system to forecast the possibility of an imminent crisis in the crisis window of 12 months by employing signal extraction methodology and logistic regression model for the period 1986 to 2015. Among the 22 identified crisis months (stress periods), only early episodes (1990-91) were followed by a devaluation but not the later periods (post 1991). Both signal extraction methodology and logistic regression model indicate no relative importance to the three generations of currency crises models. Nevertheless, the results advocate that logistic regression model fares better than signal extraction methodology, and the results also suggest that building an early warning system can be an effective diagnostic technique.

***Keywords*:** Currency Crisis; Crisis Prediction; Crisis Signals; Early Warning System; India

***JEL Classification*:** F31, F47, G01.

1. Introduction

The financial crises have enthused a huge theoretical and empirical debate in current times due to its recurrent nature in the history of economics. To highlight the importance of an economic crisis among various sections, Kaminsky *et al*. (1998) quotes Kindleberger (1978) as saying that academics are interested in it as they have had a history of fascination for the crises, policy makers are interested because they want to prevent the crisis and financial market participants are interested as they can make money out of it. The financial crises can be divided into two broad categories – *currency* and *sudden stop crises*, and *debt* and *banking crises*. Our focus in this paper is currency crisis as it has not only swept away Argentina (2001), Brazil (1998-99), Latin America (1980s), Russia (1998), Southeast Asia (1997) and UK (1992) (to name a few) but it also has caused serious economic adversities to India in the recent past (Claessens and Kose, 2013; Cerra and Saxena, 2002; Glick and Hutchison, 2013).

A currency crisis encompasses one of the following four features or a combination of them owing to a speculative attack – both successful and unsuccessful attacks – on a currency: a sharp depreciation of a currency (possibly followed by devaluation) and/or huge depletion of foreign exchange reserves or an increase in interest rates by central bank or imposing restrictions on capital flows (Edison, 2003; Glick and Hutchison, 2013; Claessens and Kose, 2013). Three generations of models[1] evolved over a period of time to explain the phenomenon of currency crisis upon the failure of previous model in explaining the subsequent crisis episode. However, the previous literature (Cerra and Saxena, 2002) and macroeconomic structure suggest that these three generations of models do not explain the Indian case completely despite the presence of some of the elements of these models.

There is a plethora of empirical studies on currency crises (Berg and Pattillo, 1999; Edison, 2003; Kaminsky and Reinhart, 1999; Kaminsky *et al*. (KLR), 1998; Bussiere and Fratzscher (2006); Licchetta, 2011; among others) but their studies are confined to a large sample of countries based on panel data or cross section data whose findings or conclusions are general but not country specific as they adopt a multicounty approach. Given the heterogeneity of the economies, there are country specific studies too (Sachs *et al*., 1996; Cerra and Saxena, 2002; Peng and Bajona, 2008; Ali Ari, 2012; Alvarez-Plata and Schrooten (2004); among others), however there is no but one study on India’s currency crisis (Cerra and Saxena, 2002). The current study emphasizes on India’s exposure to currency crisis pre and post reforms, and in fixed and managed float exchange rate systems, and the contributing factors of the crisis. This study also focuses on developing an Early Warning System (EWS) using Signal Extraction Methodology / Indicators Approach (KLR) and Logistic Regression Model, and attempts to forecast the possibilities of a crisis had the EWS been available and/or adopted. This paper also tries to find the best suitable methodology for a successful prediction of the crisis.

The remainder of this paper proceeds by providing review of literature in second section. Whereas section three presents data and selection of the variables, section four describes the methodologies we employed, section five deals with empirical estimations, and the paper ends with a conclusion in section six.

[1] See Krugman (1979) and Flood and Garber (1984) for First Generation Models, Obstfeld (1994&96) and Eichengreen *et al*. (1996) for Second generation Models, and Krugman (1998&99), Corsetti *et al*. (1999), Chang and Velasco (1998) and Aghion *et al*. (2000&2001) for Third Generation Models.

2. Literature Review

After the outburst of European Exchange Rate Mechanism (ERM) crisis – mainly in UK – in 1992, there is an abundance of empirical studies on currency crises, and selected literature was discussed below.

In a multi-country analysis, Kaminsky *et al*. (1998) found that the following indicators were useful in predicting the crisis: reserves, domestic credit, real exchange rate (RER), inflation, credit to the public sector, fiscal deficit, real GDP growth, trade balance and export performance. Whereas, Kaminsky and Reinhart (1999) attributed the worsening performance of credit, exchange rate, terms of trade, and exports as the reasons for twin crises, and it was also found that banking crisis, in general, precedes currency crisis. Edison (2003) in his empirical study said that currency crises are challenging to forecast as they are characteristically ambiguous, and he concluded that even though the EWS is helpful in identifying the vulnerable countries but it fails to identify the exact timing of the crisis. In a comparative analysis, Berg and Pattillo (1999) said that probit model performed better than KLR methodology in forecasting the crisis.

Adding to this line of research, Bussiere and Fratzscher (2006) said that multinomial logit model is a better choice to avoid *post-crisis bias*. Licchetta (2011) in a multi-country analysis found that a country's vulnerability to currency crisis increases when the size of external liabilities increases and when the neighboring country is in crisis, and RER, broad money, real GDP, current account and budget deficits were found to be leading indicators of crisis. While analyzing the effectiveness of leading indicators in predicting a crisis, Frankel and Saravelos (2012) found that reserves and RER overvaluation were significant leading indicators across the crises, and larger current accounts, saving rates, lower credit growth, lower external and short-term debt were closely entwined with lower incidence of crises even though they do cause crises.

While analyzing the nature of Argentina's currency crisis of 2002, Alvarez-Plata and Schrooten (2004) and Boinet *et al*. (2005) established that deteriorating economic fundamentals for a long period raised the devaluation expectations of peso and led to a *self-fulfilling crisis*[2]. In case of currency crises in Turkey, Mariano *et al*. (2004) found reserves, RER and domestic

[2] A crisis occurs as a result of pessimistic expectations about the economy.

credit/deposit ratio to be the key determinants of the crises, Feridun (2008) and Tamgac (2011) attributed to *self-fulfilling expectations*, and Ali Ari (2012) ascribed the causes of crises to budget deficits, RER, short-term external debt, money supply, banking sector and external shocks. Calvo and Mendoza (1996), Cole and Kehoe (1996) and Sachs *et al*. (1996) found *self-fulfilling expectations* to have precipitated Mexican currency crisis, whereas Otker and Pazarbasioglu (1996) attributed the crisis to higher inflation levels, RER appreciation, reserve losses and expansionary monetary and fiscal policies.

In an ex-post study, Peng and Bajona (2008) said that China's economic fundamentals were vulnerable enough to experience a currency crisis though it did not go through a crisis as there were restrictions on convertibility and capital flows. While studying Ethiopian currency crisis, Megersa and Cassimon (2015) found that political turmoil and external shocks as the causes apart from weak fundamentals. In examining India's currency crisis of 1991, Cerra and Saxena (2002) said that traditional models of currency crises failed to explain the Indian case but Mundell-Fleming Model, and they found that current account deficit played a significant role and external shocks damaged investor confidence in an ailing economy. In a currency crisis, Erler *et al.* (2015) said that a conservative central bank should abstain from intervention as the intervention could be successful or unsuccessful i.e., uncertainty prevails. When banks borrowed in foreign currency, Nakatani (2016) said that it is advisable to decrease policy interest rate, reserve requirement ratio and increase the interest rate on reserves since the conventional monetary policy measures are likely to effect the output negatively in twin crises.

3. Data and Selection of Variables

This paper uses monthly data for the period January 1985 to December 2015 with the aim of covering all the major events in the economy. In order to capture the dynamic nature of the economy, monthly data has been employed (Licchetta, 2011). In the estimation process, the data starts from January 1986 as the variables are percentage changes w.r.t. their previous year values[3] (Kaminsky *et al*., 1998; and Kaminsky and Reinhart, 1999) except for variables such as Excess M1 Balances (EM1B)[4], Percentage Deviation of Real Exchange Rate from its Trend

[3] We take 12 month percentage changes so as to ensure that units are stationary and free from seasonal effects (Kaminsky *et al*. 1998 & Kaminsky and Reinhart, 1999).
[4] Excess M1 Balances is defined as real M1 balances less '*estimated demand for money'*, which in turn is function of real GDP, inflation and linear time trend.

(RER), and all interest rates. We use cubic-spline interpolation method when there are missing data points and use frequency conversion method for annual/quarterly data (Kaminsky et al. (1998); Kaminsky & Reinhart (1999); Edison (2003) and Peng and Bajona, 2008; among others). Previous literature, macroeconomic structure of the economy and availability of the data were taken into account in selection of the variables – which are expected to have embodied the features of three generations of models[5] and outside – and they are as follows:

Financial Sector: M3 Multiplier, Bank Credit, Real Interest Rate, Stock Index (proxy BSE Stock Index), EM1B, M3/Reserves and Deposits; **External Sector:** Exports, Terms of Trade, RER, Imports, Reserves, Current Account Balance as a Percentage of GDP, Gold Prices and Crude Oil Prices; **Real Sector:** Output (Index of Industrial Production (IIP) is taken as a proxy); and **Fiscal Sector:** Fiscal Deficit as Percentage of GDP (Kaminsky *et al*., 1998; Kaminsky and Reinhart, 1999; Edison, 2003; among others). A detailed explanation for the inclusion of the variables and their representation of the theoretical models i.e., three generations of models, and their respective data sources can be found in the APPENDIX.

4. Methodology

The objective of this paper is to study the likelihood of a currency crisis in India and the factors contributing to it. To achieve the objective, we construct an early warning system (EWS) to identify an impending currency crisis so as to prevent and/or mitigate the crisis and its aftermath effects employing the signal extraction methodology (also known as KLR approach) and Logistic Regression Model (an alternative methodology). Building of an early warning system involves the following steps: 1. Identification of crisis months. 2. Selection of the variables based on the theoretical models, previous literature and macroeconomic structure of the economy as discussed in the earlier section. 3. Extraction of signals form the selected variables and calculating the probability of occurrence of a crisis by estimating the composite crisis index as part of the signal extraction methodology. 4. In Logit Model, we identify the factors precipitating (contributing to) the crisis and calculate the probability of a possible occurrence of a crisis. Upon building the early warning systems adopting the above two methodologies, we look into performance of the models by measuring the goodness of fit statistics of the respective

[5] See Kaminsky et al. (1998), Kaminsky & Reinhart (1999); Edison (2003); Kaminsky (2003); Peng and Bajona (2008) among others.

models. Based on the performance of the models, a suitable methodology can be chosen for building the early warning system for forecasting the possible crisis/stress periods. The above mentioned methodologies are explained below in detail.

4.1 Crisis Identification

For identification of currency crisis, we construct an index, which is referred to as *Exchange Market Pressure Index* (EMPI). We consider methodologies such as Eichengreen *et al.* (1994 & 1996), Kaminsky *et al.* (KLR) (1998 & 1999), and Frankel and Rose (1999) to capture the crises periods. We employ the KLR methodology given its superiority over other indexes and the crisis index is as follows:

$$I = \frac{\Delta E}{E} - \frac{\sigma_E}{\sigma_R}\frac{\Delta R}{R}$$

$$Crisis = 1 \; if \; I > \mu_I + \mathrm{m}\sigma_I$$

$$= 0 \; otherwise \; (I \leq \mu_I + \mathrm{m}\sigma_I).$$

In the above index $\frac{\Delta E}{E}, \frac{\Delta R}{R}$ are monthly changes in exchange rate and reserves respectively, and $\frac{\sigma_E}{\sigma_R}$ is the variance smoothing weight. In this paper, we take the value of '*m*' as 1.5 based on the previous literature (Eichengreen *et al*., 1994 & 1996; Nag and Mitra, 1999; Sevim *et al.*, 2014; Megersa and Cassimon, 2015; among others), and also to accommodate most of the unstable / volatile periods in the economy.

4.2 Noise-to-Signal Ratio and Probabilities

The below 2X2 matrix is apt in studying the efficacy of every indicator:

Table 1 – Performance of each indicator

	Crisis (in the crisis horizon of 12 months)	No Crisis (in the crisis horizon of 12 months)
Signal	A	B
No Signal	C	D

Source: Kaminsky *et al.* (1998 and 1999)

In table 1, cell A designates the number of good signals issued before an impending crisis in the crisis window of 12 months, cell B represents the number of bad signals – which are of Type II Error in nature – in the absence of a crisis, cell C symbolizes the number of missed signals – which are of Type I Error in nature – when there is a crisis in next 12 months, and cell D denotes the number of tranquil months. However, the above matrix is a modified version of KLR methodology, in which we take 12 month crisis horizon (Bussiere and Fratzscher, 2006) instead of 24 months since the macroeconomic factors are more likely to show signs of a looming crisis in shorter crisis horizon as the economy is nearer to a crisis i.e., 12 months crisis window balances the trade-off between missed and wrong signals.

When $A > 0, B = 0, C = 0 \, and \, D > 0,$ warnings by the variables will be completely accurate – wherein the noise-to-signal ratio will be zero and noise-to-signal ratio will be infinity in a contrasting case. The noise-to-signal ratio can be written as the ratio of bad signals $\left(\frac{B}{B+D}\right)$ to good signals $\left(\frac{A}{A+C}\right)$ and expressed as $\left(\frac{\frac{B}{B+D}}{\frac{A}{A+C}}\right)$. The conditional and unconditional probabilities are as follows: $\left(\frac{A}{A+C}\right)$ and $\left(\frac{A+C}{A+B+C+D}\right)$. Whereas, Type I and Type II Errors can be written as $\left(\frac{C}{A+C}\right)$ and $\left(\frac{B}{B+D}\right)$ respectively (Bussiere and Fratzscher, 2006; Edison, 2003; Kaminsky *et al.*, 1998 and 1999; and among others).

4.3 Composite Indicator

As the number of signals increases, probability of the currency crisis increases. Hence, to capture every possible crisis in the economy, we combine all the indicators.

Composite Crisis Indicator: $K = \sum_{j=1}^{n} \frac{S_t^j}{\omega^j}$

Where, $S_t^j = 1$ if the variable j exceeds the critical region at time t

$= 0$ otherwise.

And $\omega^j =$ Noise $-$ to $-$ signal ratio of variable j.

In the above equation, variables with low noise-to-signal ratio will have more weightage than which have higher noise-to-signal ratios. The composite indicator alone does not have any significance in interpretation but useful in calculating the probability of currency crisis.

4.4 Probability of Currency Crisis

Probability of crisis is calculated for every month given the composite indicator value by identifying how frequently a particular value is followed by a crisis. Probability is estimated using the following formula:

$$Pr.\left(C_{t,t+12}|K_i < K_t < K_j\right) = \frac{\sum Months\ with\ K_i{<}K_t{<}K_j\ and\ crisis\ within\ 12\ months}{Months\ with\ K_i{<}K_t{<}K_j}$$

Where, $Pr.$ designates the probability, K represents composite crisis indicator and $Pr.\left(C_{t,t+12}|K_i < K_t < K_j\right)$ denotes the probability of crisis occurrence in the crisis window of 12 months given the value of K_t lies between K_i and K_j at time t (Berg and Pattillo, 2008; Edison, 2003; Kaminsky, 2000; and Peng and Bajona, 2008).

4.5 Logit Model

As an alternative to the indicators approach, we incorporate Logit model by retaining KLR method to identify the crisis. This method allows us to see the conditional probability of currency crisis given the indicators (Ali Ari, 2012). Probability of occurrence of currency crisis p_i – wherein Y takes the value ‘one’ – follows the (cumulative) logistic distribution function:

$$p_i = E(Y = 1|X) = \frac{1}{1+e^{-(\beta_0+X'\beta)}}$$

$$= \frac{e^{\beta_0+X'\beta}}{1+e^{\beta_0+X'\beta}}$$

$$= \frac{e^{Z_i}}{1+e^{Z_i}}$$

For simplicity of explanation, we designate $(\beta_0 + X'\beta)$ as Z_i. In the above equation, X' is the vector of explanatory variables and β represents the vector of coefficients, and β_0 is the constant. Where Z_i ranges from $-\infty$ to ∞ and p_i ranges from 0 to 1. Since p_i is non-linear not only in X' but also in β, so OLS and WLS cannot be used to estimate the parameters. Hence, we use Maximum Likelihood (ML) Method to estimate the regression.

The probability of non-occurrence of crisis (1 - p_i) – wherein Y takes the value ‘zero’ – is as follows:

$$(1 - p_i) = \frac{1}{1+e^{Z_i}}.$$

Therefore the odds ratio, ratio of occurrence of currency crisis to non-occurrence of currency crisis, can be written as:

$$\frac{p_i}{1-p_i} = \frac{1+e^{Z_i}}{1+e^{-Z_i}} = e^{Z_i}$$

$$= e^{\beta_0}. e^{x_1\beta_1} \dots \dots e^{x_i\beta_i}$$

Now, taking natural logarithm on both sides of the above equation and we obtain the following form:

$$L_i = \ln\left(\frac{p_i}{1-p_i}\right) = Z_i$$

$$= \beta_0 + X'\beta_i$$

In the above equation, L_i, log of odds ratio, is not only linear in explanatory variables but also in parameters and L is called Logit. The marginal effects of the explanatory variable(s) when there is a currency crisis keeping the other variables constant can be written by taking partial derivatives on both sides of (cumulative) logistic distribution function, and the result we obtain is as follows:

$$\frac{\partial E(Y|X)}{\partial x_i} = \beta. \frac{e^{Z_i}}{(1 + e^{Z_i})^2} = \beta_i(p_i)(1 - p_i)$$

(OR)

$$= \beta_i E(Y|X)(1 - E(Y|X))$$

For estimation purpose, we take binary values since the L is unobservable, and the modified equation is as follows:

$$Y_t = \beta_0 + X_t'\beta + u_t$$

Where, $Y_t = \begin{cases} 1, & if\ there\ is\ a\ crisis \\ 0 & otherwise \end{cases}$

In the above equation, standard procedure is followed in interpretation (Maddala, 1986; Gujarati and Porter, 2003; J.S. Cramer, 2003; Bussiere and Fratzscher, 2006; and Licchetta, 2011).

5. Empirical Results

In this section, we discuss how the EMPI works in identifying the crisis in India. Whenever the EMPI crosses the threshold value, that period is considered as currency crisis but all those periods may not turn out to be full-blown crises as the fiscal and/or monetary authorities are most likely to step-in timely to pre-empt the crisis. The following months are identified as crisis months (22): June 1988, May 1989, August 1989, September 1990, October 1990, December 1990, February 1991, April 1991, June 1991, July 1991, March 1993, September 1995, October 1995, December 1997, June 1998, May 2008, September 2008, October 2008, September 2011, May 2012, June 2013 and August 2013. Among those identified months, only the early periods were consistent with devaluation (Basu, 1991) but not the later periods since any such policy action would have had countercyclical effects in the globalized economy (post reforms). Nonetheless, monetary and fiscal authorities intervened through different channels as a policy response to those crisis and/or stress periods (is discussed in next section).

[Insert Table 2 Here]

In Table 2, we choose the threshold value (critical region) – depends on the percentile distribution – for each variable separately, by executing a grid-search operation. The threshold value lies in the bottom tail of the distribution (indicated by <), if a decrease in variable is assumed to cause a crisis, whereas it falls in top tail (indicated by >), if an increase in variable is assumed to cause the crisis. Given the nature of the variable, we choose the threshold that minimizes the noise-to-signal ratio. The variables whose noise-to-signal ratios below one were the best performing ones. The predictive power of the variables in isolation is very limited as the conditional probability is always less than the unconditional probability. In addition, high probability of Type I Error implies that indicators are refraining from issuing warnings when there is an impending crisis within next 12 months. The pervasiveness of Type I Error and high unconditional probability highlight that there is no single variable that can predict currency crisis in India meaning that currency crises / stress periods in India is an amalgamation of distinct macroeconomic imbalances. These results make it necessary to go for composite crisis indicator (will be discussed soon).

[Insert Table 3 Here]

In Table 3, column 2 illustrates how accurate each indicator is in calling a crisis, whereas column 3 shows the probability of crisis followed in next 12 months given a warning. It is worth mentioning that good signals as a percentage of all possible good signals $\left(\frac{A}{A+C}\right)$ and bad signals as a percentage of all possible bad signals $\left(\frac{B}{B+D}\right)$, if calculated, are equivalent to conditional probability of crisis and Type II Error – which feature in Table 2 – respectively. The previous table does not differentiate between the signals issued before one month or 11 months about the impending crisis and to avoid this problem, we compute the average lead time (column 3), – calculates the average number of months in advance of the crisis when the first signal issued – wherein the low average of months shows that there is no single indicator that gives warnings about every impending crisis. In column 4, inverse of unadjusted noise-to-signal ratio is presented to know the persistence of signals in the crisis window relative to normal periods.

[Insert Table 4 Here]

Following Edison's (2003) method in measuring the probabilities, we present the probabilities of currency crises w.r.t. their composite crisis indicator values in table 4. The highest value of the composite index is 17 when all variables are issuing warnings whereas the maximum value of composite indicator is 69.09 but these results are most unlikely to come by as all indicators may not signal even in the severest form of the crisis. Based on the probabilities of KLR and Logit models (Logit results are presented latter), we look into early warnings issued by the variables and probabilities of the impending crises. All the crisis months prior to and during 1991 were considered as part of 1991 currency crisis, in which Fiscal Deficit, Real Exchange Rate, Reserves and M3/Reserves issued warnings during the crisis months, and this indicates that remaining indicators' ability to predict the crisis is rather poor. The KLR method predicts this crisis in next 12 months with a probability of 87%, whereas Logit model forecasts with a probability of 83%. This crisis started building up from 1988 and unfolded fully in 1991, which resulted in devaluation of rupee followed by large scale financial reforms[6]. The results are in line with the previous literature wherein this crisis was mainly attributed to fiscal mismanagement and overvaluation of rupee apart from external factors[7].

As there was an Exchange Rate Regime shift in 1993[8], the economy had seen a currency stress in 1993 due to which there was a decrease in Stock Index, Output and Real Exchange Rate. However, KLR approach was not successful in predicting this stress period as the probability was mere 30% throughout the 12 month crisis horizon whereas Logit model performed fairly well with 85% probability. Due to allegations of scams such as preferential allotment of telecommunications' contracts amid forthcoming elections, there was short spell of currency stress in 1995, and Stock Index and Bank Credit issued signals during this period whereas other indicators remained silent. The Logit model's prediction of this stress period with 86% probability shows its superiority over KLR (45%) methodology in forecasting the crisis / stress periods.

In 1997, South East Asian currency crisis had had an effect on Indian economy too, due to which Exports declined, M3 Multiplier and Real Interest Rate increased. As a result of sanctions on India by Western Forces led by USA after the nuclear tests in 1998[9], there was a currency stress in the subsequent month that resulted in a decrease in exports, stock index and an increase in M3 Multiplier but the economy recovered quickly. The prediction probabilities of the stress periods in 1997 and 1998 – KLR and Logit Probabilities were 28% and 66% respectively – were quite moderate as there were no full-blown crises like the one in 1991.

Owing to great recession in 2008, Indian economy also witnessed a short period of currency crisis, in which indicators sent warnings mainly during the crisis as it was of exogenous in nature. However, indicators such as Bank Credit, Excess M1 Balances, Gold Prices, Oil Prices and Imports issued warnings just before the crisis whereas indicators like Stock Index and Real Exchange Rate gave warnings during the crisis. This crisis was predicted by KLR methodology with the probability of 46% whereas Logit model predicted the same crisis with more accuracy with the probability of 84%. India's monetary authority Reserve Bank of India (RBI) responded

[6] See Basu (1991).
[7] See Cerra and Saxena (2002).
[8] See Dua and Ranjan (2010), p. 12.
[9] See Morrow and Carriere (1999).

to this crisis by shifting its policy stance by monetary tightening whereas Government has implemented stimulus packages as a fiscal response to the crisis[10]. However, the economy was on a steady path until the outbreak of global financial crisis of 2008 (as our results suggest).

In 2013, variables such as Current Account Balance and Deposits issued signals consistently throughout the period, and variables such as Exports, Output, M3 Multiplier, Terms of Trade, Real Exchange Rate and Gold Prices have sent signals well in advance but not consistently. However, both KLR and Logit approaches predicted this crisis fairly well with the probabilities of 87% and 86% respectively i.e., both the approaches were consistent during these episodes. This crisis had its roots from 2011 and started accumulating from then to result in currency crisis in 2013,[11] and reasons for this phenomenon may vary from policy paralysis to series of corruption allegations, and thankfully it did not turn out to be a full-blown currency crisis like 1991 though there were comparisons[12].

When the economy started showing signs of a crisis, the appointment of Raghuram Rajan as RBI new governor[13] has instilled the market confidence, we can argue, as the rupee slide stopped afterwards. Apart from this symbolic gesture, central bank's intervention[14] in foreign exchange market also helped in preventing further depreciation of rupee, and in addition, the then Prime Minister Singh made a statement in parliament about the state of the economy and rapid depreciation of the rupee[15] to bring back the normalcy in the economy. Besides this, there were also signals from the finance ministry about the ongoing economic slowdown[16]. However, it can be observed form the above results that the absence of common indicators in issuing signals (silent nature of the variables) and low average lead time indicate no relative importance to the traditional crises models.

[Insert Table 5 Here]

[10] See Global Economic Crisis and its Impact on India, Research Unit, Rajya Sabha Secretariat, GoI, June 2009; and Review of the Economy 2008-09, Economic Advisory Council to the Prime Minister, GoI, January 2009.
[11] See Subramanian (2012) and Rohit (2013).
[12] See Krishnaswamy and Kanagasabapathy (2013) and India's Economic Crisis by Simon Johnson, The New York Times, August 19, 2013.
[13] See Dr. Raghuram Rajan Appointed as Governor of RBI, PIB, GoI, August 6, 2013.
[14] See RBI to Intervene in Forex Market only to Curb Volatility: Subbarao, Live Mint, June 7, 2013.
[15] See PM's Statement on the Current Economic Situation in the Country, PIB, GoI, August 30, 2013.
[16] See Chidambaram's Appeal: Don't Buy so Much Gold, Business Standard, March 1, 2013; and Chidambaram Again Asks Indians to Lower Appetite for Gold. Here's Why, First Post, July 16, 2013.

As illustrated in table 5, we estimate binary logistic regression model – as part of the EWS – as an alternative methodology to obtain the statistically significant indicators from the above mentioned sectors and through different procedures. The explanatory variable is a binary variable (which represents currency crisis and/or stress periods), which assigns one to those months which have crossed the threshold value i.e., measured using KLR methodology and zero to the rest of the months, and the crisis horizon is 12 months same as signal extraction approach (Eichengreen *et al*., 1994 & 1996; Nag and Mitra, 1999; Berg and pattillo, 2008; Sevim *et al.*, 2014; Megersa and Cassimon, 2015; among others). We estimate two separate logit regressions by dividing the variables into two sub-categories – financial, real and fiscal sectors have been taken together to formulate model 1 and external sector has been considered for model 2 – and we estimate the overall regression (Model 3) with all significant variables form Model 1 and 2 (Ali Ari, 2012).

In model 1, M3 Multiplier, M3/Reserves, Deposits and Output are significant at 1% level and the remaining variables being insignificant shows their poor ability in forecasting the crisis. The likelihood ratio (LR) statistic – tests the overall significance of the model – being significant at 1% implies that the regression is significant but with low explanatory power as the pseudo R^2 – presents the fitness of the model – is very small (0.115). Whereas in model 2, Exports, Imports, Current Account Balance and Gold Prices are significant at 1% and Reserves are significant at 10%. The LR statistic is significant at 1% same as the model 1 and pseudo R^2 is 0.318 implying that model 2 has a better explanatory power than model 1 i.e., external sector's ability to explain currency crises and/or stress periods in India is superior than other sectors' ability.

In model 3, coefficients of Deposits, Imports, Current Account Balance and Gold are significant at 1%, and M3 Multiplier and M3/Reserves are significant at 5% whereas Exports and Output are significant at 10%. With significant LR statistic (1%) and better pseudo R^2 (0.408), model 3 does better than model 1 and 2 (of course model 3 is the combination of the first two models) (Ali Ari, 2012; Ari and Cergibozan, 2016). Following the same pattern in Model 4, it has been estimated taking all the significant variables from running bivariate regressions (Frankel and Saravelos, 2012). In model 4, M3 Multiplier, Deposits, Imports, Current Account Balance and Gold Prices are significant at 1% whereas Oil is significant at 10%, and model 4 is quite robust with significant LR statistic (1%) and a value of 0.395 pseudo R^2. Using the stepwise regression method (backward selection), model 5 has been estimated. Variables such as Bank Credit, Real Interest Rate, M3/Reserves, Stock Index, Imports, Reserves, Current Account Balance and Gold are found to be significant at 1% level whereas M3 Multiplier and Real Exchange Rate are significant at 5%, and Output is significant at 10%. The overall fitness of the model 5 is quite good with a significant LR statistic (1%) and fairly better value of pseudo R^2 (0.517).

[Insert Table 6 Here]

Among the last three models, model 5 performs better in terms of goodness of fit and significance of the variables in forecasting the crisis, hence model 5 was considered in calculating the probability of crisis and in building the early warning system (EWS), and we've used these probabilities to explain the crisis in the previous sections along with the probabilities based on KLR approach. Variables such as M3 Multiplier, Deposits, Imports, Current Account Balance and Gold Prices are significant across the models, whereas variables like M3/Reserves, Reserves and Output are significant at least in two models. These results show that currency crises in India are due to an amalgamation of various macroeconomic inconsistencies as these variables represent different sectors and theoretical models, which are in line with KLR results i.e., there is no relative importance to three generations of currency crisis models (significant variables are from all three generations of models and beyond). It can be noticed from table 6 – which can be considered as a robustness check for early warning systems based on KLR approach and Logit model – that all logit models outperform KLR model in terms of goodness-of-fit at all cut-off probability levels – 25%, 50% and 75%. At cut-off probability of 50%, all the logit models perform slightly better than remaining two probability levels, whereas KLR model fares better at 75% than other cut-off levels.

However, KLR model can be used as a benchmark methodology in identifying the crisis periods and calculating probabilities of crisis occurrence, and alternative methodologies such as Logit can be employed to further strengthen the ability to forecast the crisis, and the advantage with KLR methodology is that we can see which all variables are causing the crisis in every episode (month) unlike other methods. However, based on our results Logit model can be recommended to construct the EWS to predict the crisis/stress periods. Looking at all the crisis episodes and/or stress periods in last three decades, what we can infer is that irrespective of the exchange rate regimes as the previous literature suggest (Flood and Garber, 1983; Aghion *et al*., 2001) and macroeconomic structure, the Indian economy – stable for a decade (1998-2008) – is still vulnerable to currency crisis though the severity may vary subject to pre-emptive measures taken by the fiscal and monetary authorities. Nonetheless, building an EWS may not (necessarily) guarantee the prevention of a looming crisis but it can be a useful diagnostic tool despite its limitations related to distribution and assumptions (Edison, 2003).

6. Concluding Remarks

In this paper, we focus on the recent history of currency crises and/or stress periods in India. The KLR and Logit models have been employed to find out the factors contributing to the crisis, to build the EWS, and to see the likelihood of currency crisis in India. Both these models perform well in predicting the crisis in this ex-post study. Nevertheless, Logit model fares better than KLR methodology in terms of the goodness-of-fit measures (and probabilities). It was found that there were no common indicators across the crisis episodes in case of KLR method, whereas in Logit model, variables such as M3 Multiplier, Deposits, Imports, Current Account Balance, Gold Prices, M3/Reserves, Reserves and Output were found to be significant. Both these methodologies indicate that there is no relative importance to the three generations of models, and also show that currency crisis in India is due to combination of different macroeconomic imbalances. Though Indian economy seems to be more stable for a decade from 1998 to 2008 (until global financial crisis) but it is still not immune to currency crisis as the results advocate. Findings of this study suggest that building an EWS – by adopting Logit model in addition to KLR model – would be helpful in forecasting the impending currency crisis as a diagnostic tool despite its limitations. However, EWS based on logit model can be recommended to policy makers. There is ample room for future research, if variables such as political factors, contagion and trade agreements are taken into account.

APPENDIX

List of Variables

Name of the Variable	Explanation	Data Source	Generation of the Model
M3/Reserves	Captures to what extent the liabilities of the banking system are backed by international reserves.	Handbook of Statistics on Indian Economy, RBI and IMF IFS Database	Third Generation
Excess Real M1 Balances	Loose monetary policy	Handbook of Statistics on Indian Economy, RBI and IMF IFS Database	First Generation
Fiscal Deficit as % of GDP	Loose fiscal policy	Bloomberg Database and Handbook of Statistics on Indian Economy, RBI	First Generation
Deviation of Real Exchange Rate from Trend (in % terms)	Overvaluation of the currency	IMF IFS Database	Second Generation
M3 Multiplier (M3/M0)	Rapid growth of money supply	Handbook of Statistics on Indian Economy, RBI and IMF IFS Database	Third Generation
Domestic Credit	Credit expansion	Handbook of Statistics on Indian Economy, RBI	Third Generation
Deposits	Loss of deposits as crisis unfolds	Handbook of Statistics on Indian Economy, RBI	Third Generation
Oil Prices	High oil prices associated with recessions	IMF IFS Database	NA
Real Interest Rate	Its increase indicates credit crunch / Higher interest rate indicates higher risk premium and default expectations	Handbook of Statistics on Indian Economy, RBI	Second Generation
Terms of Trade	A decrease in TOT indicates the crisis	World Development Indicators	Second Generation
Gold Prices	Effects reserves through exchange rate	World Gold Council	NA
Output	A rapid decline in output indicates the recession	IMF IFS Database	Second Generation

Stock Index	Burst of asset prices	BSE Index	Third Generation
Reserves	Rapid depletion of reserves is a strong indication of a crisis	IMF IFS Database	NA
Current Account Balance	Current Account Deficit strongly effects reserves through exchange rate whereas rapid increase in imports and decrease in exports are strong indicators of a crisis	Bloomberg Database	NA
Exports		IMF IFS Database	Second Generation
Imports		IMF IFS Database	Second Generation

Source: Kaminsky et al., 1998; Kaminsky and Reinhart, 1999; Edison, 2003; Ali Ari, 2012; among others.

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TABLES

Table 2 – Efficiency of the Indicators

Indicator	Threshold Percentile	Noise to Signal Ratio	Con. Prob. of Crisis	Uncon. Prob. of Crisis	Prob. (Type I Error)	Prob. (Type II Error)
Financial Sector						
M3 Multiplier	>79	1.093	0.197	0.394	0.802	0.216
Bank Credit	>75	1.181	0.225	0.394	0.775	0.266
Real Interest Rate	>95	0.651	0.063	0.394	0.937	0.041
Excess M1 Balances	>92	0.565	0.107	0.394	0.894	0.060
M3/Reserves	>92	0.024	0.190	0.394	0.810	0.005
Deposits	<30	1.861	0.197	0.394	0.803	0.367
Stock Index (BSE)	<24	1.046	0.232	0.394	0.768	0.243
External Sector						
Terms of Trade	<11	0.558	0.148	0.394	0.852	0.083
Exports	<27	1.207	0.240	0.394	0.761	0.289
Real Exchange Rate	<14	0.707	0.169	0.394	0.830	0.119
Imports	>95	0.521	0.070	0.394	0.930	0.037
Reserves	<10	0.186	0.197	0.394	0.803	0.037
Current Account Balance	<10	0.081	0.225	0.394	0.775	0.018
Gold Prices	>95	0.717	0.070	0.394	0.930	0.037
Crude Oil Prices	>94	0.717	0.070	0.394	0.930	0.050
Real Sector						
Output (IIP index)	<18	0.651	0.225	0.394	0.775	0.147
Fiscal Sector						
Fiscal Deficit	>83	0.273	0.303	0.394	0.697	0.083

Source: Authors' Calculations

Table 3 – Performance of the Indicators

Indicator	Percentage of Observations Correctly Called	Prob. (Crisis/Signal)	Average Lead Time	Persistence of Signals
	(A+D) / (A+B+C+D)	A/(A+B)		
Financial Sector				
M3 Multiplier	0.553	0.373	2	0.59
Bank Credit	0.533	0.356	3	0.55
Real Interest Rate	0.605	0.500	1	1
Excess M1 Balances	0.611	0.536	2	1.15
M3/Reserves	0.681	0.964	4	27
Deposits	0.461	0.259	3	0.35
Stock Index (BSE)	0.550	0.384	2	0.62
External Sector				
Terms of Trade	0.614	0.538	2	1.17
Exports	0.525	0.351	4	0.54
Real Exchange Rate	0.600	0.480	3	0.92
Imports	0.611	0.556	2	1.25
Reserves	0.661	0.778	4	3.50
Current Account Balance	0.683	0.889	2	8
Gold Prices	0.611	0.556	1	1.25
Crude Oil Prices	0.603	0.476	3	0.91
Real Sector				
Output (IIP index)	0.606	0.500	4	1
Fiscal Sector				
Fiscal Deficit	0.675	0.705	5	2.39

Source: Authors' Calculations

Table 4 – Probabilities of Currency Crises

Value of Composite Indicator	Probability of Crisis
0-0.5	0.43
0.5-1.0	0.29
1.0-1.5	0.05
1.5-2.0	0.45
2.0-2.5	0.12
2.5-3.0	0.30
3.0-5.0	0.14
5.0-7.0	0.37
7.0-9.0	0.67
Above 9	0.87

Source: Authors' Calculations

Table 5 – Logit Estimation Results

Indicator	Model 1	Model 2	Model 3	Model 4	Model 5
Financial Sector					
M3 Multiplier (M3M)	-0.112*		-0.084**	-0.104*	-0.117**
	(0.029)		(0.042)	(0.038)	(0.047)
Bank Credit (BC)	-0.037				-0.103*
	(0.024)				(0.036)
Real Interest Rate (RIR)	0.047				0.372*
	(0.041)				(.073)
Excess M1 Balances (EM1B)	0.0001			0.0004	
	(0.0002)			(0.0002)	
M3/Reserves (M3/R)	0.018*		0.029**	0.003	0.059*
	(0.006)		(0.011)	(0.005)	(0.018)
Deposits (Dep.)	0.163*		0.245*	0.255*	0.424*
	(0.046)		(0.053)	(0.058)	(0.078)
Stock Index (BSE) (SI)	-0.002				-0.020*
	(0.003)				(0.007)
External Sector					
Terms of Trade (ToT)		0.007		0.001	
		(0.008		(0.009)	
Exports (Exp.)		0.041*	0.028***	0.0217	
		(0.013)	(0.014)	(0.014)	
Real Exchange Rate (RER)		0.029			0.063**
		(0.019)			(0.028)
Imports (Imp.)		0.029*	0.041*	0.038*	0.074*
		(0.010)	(0.011)	(0.011)	(0.013)
Reserves (R)		0.007***	0.018**		0.034*
		(0.004)	(0.008)		(0.012)
Current Account Balance (CAB)		1.439*	1.455*	1.442*	2.342*
		(0.191)	(0.201)	(0.189)	(0.312)
Gold Prices (Gold)		-0.061*	-0.074*	-0.098*	-0.086*
		(0.012)	(0.013)	(0.016)	(0.016)
Crude Oil Prices (Oil)		0.003		0.009***	
		(0.005)		(0.005)	
Real Sector					
Output	-0.092*		-0.063***		-0.084***
	(0.029)		(0.036)		(0.043)
Fiscal Sector					
Fiscal Deficit (FD)	0.026			0.201	
	(0.110)			(0.125)	
Constant	-1.953**	-3.512*	-7.534*	-8.656*	-10.478*
	(0.978)	(0.415)	(1.140)	(1.436)	(1.640)
No. of Observations	360	360	360	360	360
Likelihood Ratio Statistic	55.74*	153.83*	196.78*	190.50*	249.49*
Pseudo R^2	0.115	0.318	0.408	0.395	0.517

[Table 4 Presents the Results of the Following Equations:

$$Model\ 1:\ Y_t = \beta_0 + \beta_1 M3M_t + \beta_2 BC_t + \beta_3 RIR_t + \beta_4 EM1B_t + \beta_5 (\frac{M3}{R})_t + \beta_6 Dep_t + \beta_7 SI_t + \beta_{16} Output_t + \beta_{17} FD_t + e_t$$

$$Model\ 2:\ Y_t = \beta_0 + \beta_8 ToT_t + \beta_9 Exp_t + \beta_{10} RER_t + \beta_{11} Imp_t + \beta_{12} R_t + \beta_{13} CAB_t + \beta_{14} Gold_t + \beta_{15} Oil_t + e_t$$

$$Model\ 3:\ Y_t = \beta_0 + \beta_1 M3M_t + \beta_5 (\frac{M3}{R})_t + \beta_6 Dep_t + \beta_9 Exp_t + \beta_{11} Imp_t + \beta_{12} R_t + \beta_{13} CAB_t + \beta_{14} Gold_t + \beta_{16} Output_t + e_t$$

$$Model\ 4:\ Y_t = \gamma_0 + \gamma_1 M3M_t + \gamma_4 EM1B_t + \gamma_6 Dep_t + \gamma_8 ToT_t + \gamma_9 Exp_t + \gamma_{11} Imp_t + \gamma_{13} CAB_t + \gamma_{14} Gold_t + \gamma_{15} Oil_t + \gamma_{17} FD_t + \varepsilon_t$$

$$Model\ 5:\ Y_t = \delta_0 + \delta_1 M3M_t + \delta_2 BC_t + \delta_3 RIR_t + \delta_5 (\frac{M3}{R})_t + \delta_6 Dep_t + \delta_7 SI_t + \delta_{10} RER_t + \delta_{11} Imp_t + \delta_{12} R_t + \delta_{13} CAB_t + \delta_{14} Gold_t + \delta_{16} Output_t + \epsilon_t$$

Note: *, ** and *** Denote Statistical Significance at 1%, 5% and 10% Levels Respectively. Standard Errors in Parentheses]

Table 6 – Performance of the Models

Goodness of Fit	KLR	Model 3	Model 4	Model 5
Cut-off Probability of 25%				
% of Tranquil Periods Correctly Called	50	84	85	87
% of Observations Correctly Called	66	91	91	92
% of Crises Correctly Called	89	100	100	100
% of False Alarms of Total Alarms	46	19	18	16
% Prob. of Crisis Given an Alarm	54	81	82	84
% Prob. of Crisis Given No Alarm	12	0	0	0
Cut-off Probability of 50%				
% of Tranquil Periods Correctly Called	94	99	100	100
% of Observations Correctly Called	77	99	100	100
% of Crises Correctly Called	50	100	100	100
% of False Alarms of Total Alarms	14	1	0	0
% Prob. of Crisis Given an Alarm	86	99	100	100
% Prob. of Crisis Given No Alarm	26	0	0	0
Cut-off Probability of 75%				
% of Tranquil Periods Correctly Called	95	100	100	100
% of Observations Correctly Called	76	89	87	91
% of Crises Correctly Called	47	73	67	78
% of False Alarms of Total Alarms	13	0	0	0
% Prob. of Crisis Given an Alarm	87	100	100	100
% Prob. of Crisis Given No Alarm	27	15	18	12

Source: Authors' Calculation