Measuring the effectiveness of signals approach in an early warning system for crises and its impact on textile industry: a case study for South-East Asia

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ABSTRACT – REZUMAT

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Following the work of Kaminsky, Lizondo, and Reinhart (1997), Signals Extraction Approach has been adopted with some extensions for South-East Asian (SEA) region to investigate the performance of the technique as an Early Warning System (EWS) during Asian Financial Crisis (AFC) and Global Financial Crisis (GFC). This approach is very original in the context of investigating the impact on the dynamics of the textile industry in South-East Asia. Two additional approaches namely Signal to Noise Balance (STNB) and Kuipers Score (KS) have also been utilised. Outcome suggested that variables performed well both during AFC and GFC. However, predictive ability of variables was less during GFC compared to the AFC indicating that there may exist some complex phenomenon which requires composite statistical methods.

Keywords: *early warning system, financial crises, signals, signals to noise balance, Kuipers score, South-East Asia, textile industry*

Măsurarea eficacității semnalelor într-un sistem de avertizare timpurie pentru crize financiare și impactul asupra industriei textile: studiu de caz pentru Asia de Sud-Est

În urma lucrărilor științifice publicate de către Kaminsky, Lizondo și Reinhart (1997), abordarea privind extragerea semnalelor a fost adoptată cu unele extensii pentru regiunea Asiei de Sud-Est. Scopul principal al acestui studiu empiric este acela de a investiga performanța tehnicii menționate anterior ca Sistem de avertizare timpurie (EWS) în timpul perioadei crizei financiare asiatice, precum și în timpul și crizei financiare globale. Această abordare este originală în contextul analizei impactului asupra dinamicii industriei textile din Asia de Sud-Est. Au fost, de asemenea, utilizate două metodologii econometrice suplimentare, și anume Raportul Semnal-Zgomot (STNB) și Scorul Kuipers (KS). Rezultatul a sugerat că variabilele au avut rezultate bune atât în timpul crizei financiare asiatice, cât și în perioada crizei financiare globale. Cu toate acestea, capacitatea predictivă a variabilelor a fost mai mică în timpul crizei financiare globale comparativ cu criza financiară asiatică, indicând că poate exista un fenomen complex care necesită metode statistice compozite.

Cuvinte cheie*: Sistem de avertizare timpurie, crize financiare, semnale, Raportul Semnal-Zgomot, Scorul Kuipers, Asia de Sud-Est, industria textilă*

INTRODUCTION

Financial crises have become relatively frequent events since the beginning of the 1980s [1] and are observed in three primary forms which are: debt crises, currency crises and banking crises (both latter crises are collectively called as twin crises). These events have contributed to an increased interest in the matters of the financial market's problems and its instability. Financial crises in general are not singular events and have been occurring from time to time and actually are the product of the errors committed in the financial sector. They are disconcerting events which at first seem impenetrable, but soon their damage undeniably grows and becomes more and more widespread. Moreover, there often lie obscure and complicated financial institutions and instruments, e.g. program trading during the 1987 stock market crash, junk corporate bonds in the savings and loan debacle in the early 1990, the technology stock blast, and many more are examples of it. Realising the nature and severity of crises is really important because of the huge costs attached to them and therefore such issues are required to be forestalled. Early Warning Systems (EWS) offer a secure platform to study and anticipating such events with the aid of models/techniques to assist policy makers in determining how to react to the upcoming heat and as a solution, either crises can be prevented or at least their impact can be softened. Yildiz [2] suggested that nowadays to establish an effective chain of supply has become one of the prerequisites for the survival of the companies in an environment of increasing competition with the effect of the globalization. There are few techniques available to be

utilised as an EWS and from time to time there have been an increase in them because of the nature of crises and with the invention of new techniques and approximations. However, a technique which has been vastly used as an EWS: Signals extraction approach has its own significance when it comes to crisis assessment.

Sugihara [3] discussed important issues regarding the so-called “Asian textile complex” in the 1970s, in which Japan produced rayon yarn, Taiwan wove rayon cloth, and Hong Kong made the cloth into an apparel and exported the apparel to the US. Verret [4] highlighted relevant aspects regarding textile industries of lower-wage countries of South-East Asia. Frynas [5] suggested that in certain developing countries in Asia such as China, the Philippines and Indonesia, human rights standards are lower, and garment firms violate some of the key internationally accepted human rights.

As an initial step towards investigating the conduct of financial crises, this paper has applied signals approach to the selected region in order to investigate that how efficient and helpful is this approach in capturing the crises episodes during the Asian financial crisis and can global financial crisis also be captured? For this purpose, few additional steps have also been taken to make the study more concrete and reliable. This can assist in building consensus onto which tools should be utilised and what characteristics they should bear in order to better capture such disturbances. In the following section, some of the literature is reviewed based on crises and the tools which have been used frequently in the past. As a succeeding step, details are provided on methodology directing how to work on an early warning system which include; defining of objectives, country coverage, time period, the method used, the variables selected. The details about the main technique applied, which is signals approach, are discussed separately. Consequently, results, discussion and analysis section is provided, followed by the conclusion of the study.

LITERATURE REVIEW

Financial markets have always taken on new strategies to cope with the ambiguities and learnt many lessons from the history of crises. Although, the response of such markets was largely reactive instead of being proactive, but still markets learnt enough to avoid past mistakes to be replicated in the future. The learning procedure is rather complex, but nevertheless it can be resumed based on the model studies which are recognized to be generation models that capture the symptoms of distress ranging from recessions to exaggerated cycles in credit markets. Three of such major categories which have been talked about previously are reviewed here to some extent. Krugman’ model of currency crises which is well known to be as a first generation model of currency crises developed in the light of Latin American crises of the 1960s and 1970s suggested that, under a specified exchange rate, domestic credit expansion in excess of money demand growth leads to gradual and persistent loss of reserve levels and which in fact can create a speculative attack on the currency [6]. If attacks occur, can immediately deplete the reserves and authorities can be forced to abandon the parity. This process usually ends with the attack because economic agents understand that fixed exchange rate will collapse ultimately and in case of attack, they can suffer a capital loss on their holdings of domestic money. Krugman’ work has been extensively expanded and these extensions have shown that speculative attacks would generally come before with a substantial currency appreciation and trade-balance deterioration [7]. Krugman’s idea gave a bunch of thought processes and understanding, however, it was not in accordance with the occurrence of later crises therefore it was declined because many of such crises happened without that explained phenomenon. As a consequence, some other explanation was taken of what was left unexplained in first generation models.

Currency crises in the European Monetary System (EMS) 1992–1993 and Mexican crisis of 1994–1995 gave rise to second generation models of crises. These models indicated that the decision to give up the parity may stem from the authorities’ concern about the development of other key economic variables. Ozkan and Sutherland [8] suggested a model which explained the aim of the authorities to maintain the exchange rate specified on the basis of certain values. It is founded on the benefits gained from maintaining the exchange rate fixed and deviations of output going beyond certain levels. Later models also suggested that crises may arise without any detectable change in the economic fundamentals as the contingent nature of economic policies can give rise to multiple equilibria and generate self-fulfilling crises; an idea very similar to Obstfeld work [9]. The Models also indicated that the market can achieve equilibrium with favourable as well as adverse economic fundamentals depending on the expectations of investors and their respective activities. The unexplained reasons for expectations shift required another model which could explain such reasons. The next generation of models for crises were developed after the 1994–1995 Tequila crises and the Asian financial crisis in 1997–1998. Aside from the recognition that the behaviour of market participants influences also the decisions of policymakers, the chief features of those mannequins are the integration of moral hazard, information asymmetries, herding and contagion effects [10]. These models were better as they could explain whatever the previous generation models were unable to explain, especially anything which was not based on fundamentals. Convincingly, these generation models describe the build-up of crises and the reasons for them on a timeline which gives a thorough understanding about the occurrences of crises with the passage of time.

With regards to crises and its estimation, it is always advantageous to have a common set of constituents,

which might cause those disruptions. Recent empirical research showed that although the causes of crises are not equal, however, they are connected to each other on a bigger chassis. Kaminsky [11] showed that most of the past crises were characterized by a large number of weak economic fundamentals, suggesting that it would be hard to characterise them as self-fulfilling crises. Thus, any new attempt is always an advantage in order to get early warning models to detect such weaknesses in advance to allow policymakers to consider appropriate steps well ahead to at least minimise the effects of such turbulences. There are a few techniques which have been applied in the past as early warning systems in crises and such techniques have been very helpful in anticipating crises. These applications in early warning systems follow some major methodological model approaches: i) the leading indicator approach, ii) the linear-dependent variable approach, iii) the discrete-dependent variable approach, iv) other approaches apart from the three aforementioned ones, such as artificial neural networks, latent variable threshold models, autoregressive conditional hazard models and Markov regime switching models [12].
The linear dependent variable approach has been used in many fields. In the field of financial economics, consider for example, Sachs, Tornell and Velasco [13] in which the survey analysed the Mexican crisis in 1994–95 and its aftermaths. The model used three explanatory variables using linear regression to determine whether a country is vulnerable to a crisis and applied a crisis index, which was a weighted average of the devaluation of the exchange rate against the USD and the percentage change in foreign exchange reserves. Explanatory variables included the percentage changes in i) the real depreciation of the exchange rate ii) the ratio of the size of the claims of the banking sector to the private sector to GDP which captures the resilience and weakness of the banking sector, and iii) the reserve adequacy measured as M2 to the stock of foreign exchange reserves. The linear regression captured even small alterations in the explanatory variables because of the steady dependent variable.
Nevertheless, non-linearities were not captured. After analysing, the survey concluded that the combination of overvalued exchange rates, recent lending booms and low reserves relative to short-term commitments of the central bank are contributors to the crises and the current account data, capital flows and fiscal policies do not provide further explanatory power.
A cornerstone study in the early warning framework of leading indicators approach was carried by Kaminsky, Lizondo and Reinhart [14]. In this approach, signals are extracted from a set of indicators and these signals are then channelled to generate information for crisis occurrence or non-occurrence. Although traditionally, this approach has been used to predict business cycle turning points, however, because of its easy to use features, this approach has been extensively applied in the EWS literature and is considered among the best EWS approaches available. An overview of the performance of various crises models, which were tracked by the international monetary fund, provides some information regarding EWS and their probability of predicting the crises. For example, Berg, Borensztein and Pattillo [15] compared the models from the IMF's Developing Country Studies Division (DCSD) and Kaminsky, Lizondo and Reinhart [16], with three private sector models from Goldman Sachs, Credit Suisse, First Boston and Deutsche Bank, which have short signalling windows. Out of the five models, KLR [16] model performed best in the relevant out-of-sample test. The private sector models performed poor out-of sample, although, the in-sample performance of all the models was satisfactory.

OBJECTIVES OF THE CURRENT STUDY

The current study is dedicated to developing an early warning system with the help of existing signals approach along with some modifications in order to analyse the crises and also to test the model' performance based on the selected variables for the region under consideration. Although there have been criticism on signals approach, its advantages and easy to use features cannot be ignored given its ability to perform very well in situations where complex modelling is not preferred. The analysis of the study helps to determine the crisis probability and hence the predictive ability of the model.

RESEARCH METHODOLOGY

In order to carry out EWS, some basic steps need to be followed. These steps assist in investigating the crisis with convenience. Each step is therefore explained separately to provide better understanding about application of the EWS.

Defining the crisis

The first and most important step is to define the crisis as crisis can have many diverse definitions depending upon the way the research is being conducted. The current study has followed the definition of KLR [16] and a crisis is defined as a situation in which the Exchange Market Pressure Index (EMPI) is above its mean position by more than 1.5 standard deviation i.e.

$$Crisis = \begin{cases} 1 & \text{if } EMPI_t > \mu_{EMPI} + 1.5\,\sigma_{EMPI} \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Exchange market pressure index is calculated based on the changes in exchange rate, interest rates, and the level of reserves as defined by Kaminsky and Reinhart [16]. This index includes nominal exchange rate, interest rate and change in reserves. Negative changes in reserves and positive changes in exchange rate and high interest rate indicate that the pressure on the market is increasing [17]. In theory, the calculation of the index is done by focusing on each of the variable and observing their behaviour. *EMPI* can be generated using the following formula:

$$EMPI_t = \frac{\left(\frac{NER_t}{RES_t}\right) - \mu_{NER}}{\sigma_{NER}} \quad (2)$$

$$\int_t = \left(\frac{dINT_t - dINT_{t-12}}{dINT_{t-12}}\right) \quad (3)$$

$$NER_t = \left(\frac{dNER_t - dNER_{t-12}}{dNER_{t-12}}\right) \quad (4)$$

$$RES_t = \left(\frac{dRES_t - dRES_{t-12}}{dRES_{t-12}}\right) \quad (5)$$

where d in the $dINT_t$, $dNER_t$ and $dRES_t$ represents the 12 months percentage change of the variables. In the above equations, $\int_t$, NER_t and RES_t represents the nominal exchange rate, interest rate, and reserves respectively, whereas, μ and σ represents the respective mean and the standard deviation of the variables respectively. This unusual behaviour is identified for each indicator and a signal is issued when it reaches certain extreme levels, called threshold point, and cross that threshold. *EMPI* will generate a crisis signal when it surpasses the threshold point.

Choice of variables

A number of 26 variables in total were chosen in the study to cover different sectors. The variables are subject to the availability of data from the selected six countries, i.e. Indonesia, Malaysia, Philippines, Singapore, South-Korea, and Thailand. For all the variables (except variables based on rates and the ratio based variables), the indicator on a specific month is defined as a percentage change in the level of the variable with respect to its level 12 months ago. This transformation of data based on 12-months adjustment ensures that the data is comparable across countries and the variables are free from seasonal effects, stationary, and with well-defined moments.

Countries coverage

This study focused on selected ASEAN+ economies which covers Indonesia, Malaysia, Philippines, Singapore, South-Korea, and Thailand, with developed economies (Singapore and South-Korea) and Emerging Market Economies (EME) (Indonesia, Malaysia, Philippines, and Thailand). This combination of countries provides opportunity to examine the behaviour of crises for different economies. KLR [14] suggested that, in order to select a country for the analysis, it should have encountered at least one crisis in the past. All the selected countries fulfil this requirement.

Time period covered

The study used 222 observations from January 1993 to June 2012 from ASEAN countries. In the case of unavailability of monthly data, interpolated data from quarterly observations were taken. However, if no observations were available for any variable, then these variables are not included in the calculations of signals as otherwise that variable will get penalized and it will affect the probability of overall results. Moreover, the data was divided into two different sample periods which are in-sample and out of sample. Data on which the model has been applied and results have been generated primarily is called in-sample data and it includes the time period from January-1993 to December-2003 which covers the Asian financial crisis. The remaining data has been used to test the performance of the model and is called out-of-sample data which includes the time period from January-2004 to June-2012 which covers the global financial crisis. In the study, there is a signalling horizon which is the time prior to the onset of a financial crisis, within which variables are supposed to give warnings for a possible occurrence of the crisis. The current study used a priori 15-months crisis window to generate and issue signals before the crisis could erupt so that policy makers and authorities have reasonable time to deal with the situations.

SIGNALLING EXTRACTION METHOD

Signal extraction method is a technique which captures the behaviour of the variable(s) on a certain scale and then each indicator is analysed separately within this univariate approach to observe a crisis. Therefore, the behaviour of each indicator is monitored to identify its deviation from its normal behaviour beyond a certain threshold. If an indicator crosses that threshold level, it is said to issue a signal. For better explanation, a signal can be defined and captured on a binary scale variable. Let "X" denotes a vector of the "n" indicators and "$X_{t,j}$" denotes the value of indicator "j" in time period "t", then the signal "$S_{t,j}$" of indicator "j" in time period "t" on a binary scale is defined as:

$$S_{t,j} = \begin{cases} 1 & \text{if } |X_{t,j}| > |X_t^j| \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

where $|X_t^j|$ is the threshold value for that particular variable. If any variable crosses that threshold, it will provide a signal for a crisis.

Performance of indicators

To determine the performance of the indicators, the signalling window is defined as a time period within which each variable is expected to show its sensitivity for anticipating crisis. In this study, the period of 15 months is selected to capture the signalling prior to and after the known date of the crisis; a collective period of 30 months. The reason to keep a window of 15 months on both sides is to provide enough time for variables to respond because in some situations, certain variables are more affected later on or immediately after the crisis but not before. So, this period of 30 months, captures the behaviour of variables under all the possible circumstances. The behaviour of each variable can be explained properly with the help

of a crisis matrix to aid in understanding the terminologies applied in the approach. Table 1 represents the matrix in which, if an indicator issues a signal within the provided window preceding a crisis, this signal is considered as a good signal. However, if a signal is not followed by a crisis within a given time period, it is called a bad signal or noise. The ratio of false signals to good signals is called noise-to-signal ratio and it plays a vital role in calculating the goodness of fit of the model. However, if the variable does not signal any crisis followed by a crisis within the time period, it is taken as a missed signal and if no signal was issued followed by no crisis then it is taken as a good silence.

Table 1

CRISIS MATRIX		
	Crisis within 30-months	**No Crisis within 30-months**
Signal Issued	A	B
No Signal Issued	C	D

Note: *A* – Good Signal: Period in which an indicator issued a signal followed by the crisis within given time period; *B* – Bad Signal: Period in which an indicator issued a signal followed by no-crisis within a given time period; *C* – Missed Signal: Period in which an indicator issued no signal and crisis occurred within a given time period; *D* – Good Silence: Period in which no signal was issued, followed by no crisis.

Noise to signal ratio is defined as follows:

$$Noise\text{-}signalratio(\omega) = NTSR = \frac{B/B+D}{A/A+C} = \frac{\beta}{1-\alpha} \quad (7)$$

It is the ratio of bad signals to the months in which bad signals could have been issued to the good signals over the months in which good signals could have been issued. α and β are type-I and type-II errors respectively. The lower the *NTSR* is, the better is the performance of the variable as less and less false signals will be issued. However, in reality, *NTSR* is adjusted in a way where a low combination between type-I and type-II errors can be found.

$$\text{Type I error } (\alpha) = C \,/\, A{+}C \quad (8)$$

$$\text{Type II error } (\beta) = B \,/\, B{+}D \quad (9)$$

Where type-I error is the chance of missing a crisis when actually there is a crisis and type-II error is the chance of alarming false crisis when there is no crisis in reality. The variables with least value in terms of noise to signal ratio are considered as best and more accurate. Based on the information from *NTSR*, a decision criteria can be formulated on to which variables to keep and which ones to eliminate from the set of possible variables as noisy variables that are not preferable. In order to generate the optimal set of threshold for each indicator, KLR [14] method was followed and the thresholds were defined in relation to the percentiles of the distribution of observation of the indicators. Percentiles were chosen and an optimal level of percentile was selected according to one that minimizes the noise-to-signal ratio. Percentile level chosen for each indicator is uniform across countries, but its corresponding country specific threshold values would most probably differ.

Signal to Noise Balance and Kuipers Score

In order to compare the performance of the variables, two additional comparative measures have also been considered which can suggest the goodness of fit for the approach. These measures are Signal to Noise Balance (STNB) firstly implemented by Rocha, Perrelli and Mulder [18] and Kuipers Score (KS) as applied in Berg, Candelon and Urbain [19]. Signal to noise balance is the difference between the percentage of pre-crisis periods called correctly and the percentage of false alarms.

$$STNB = (A - B) \,/\, (A + C) \quad (10)$$

The advantage of using this approach is that the relative number of classified incidents (crisis alarms "C", tranquil periods "D") does not affect the ratio as explained by Oka [20]. This ratio is easily interpretable in a sense that it can reach a maximum value of 100 when all pre-crisis periods are called correctly and no false alarms are issued. The difference is negative when model issues more false alarms than good alarms per pre-observed crisis periods. On the other hand, Kuipers Score is a difference between no. of good signals to the total good signals during crisis period and no. of bad signals to the total bad signals during that period respectively.

$$KS = A/(A + C) - B/(B + D) \quad (11)$$

KS is used as a goodness of fit for indicators as the indicators are considered to be performing better if their *KS* is towards positive side and a score of 1 will show that a variable indicator correctly called 100% of the crisis. These scores are meant to give an indication of the average closeness of the predicted probabilities and the observed realizations.

Composite indices

In order to collect all the compulsory information from the signalling extraction and other applied methods, the formulation of the composite index is required as with the help of it, time-varying probability of a crisis can be mapped. Not only this, but it can also combine the information obtained from the individual indicators in a meaningful way. It can be realized that the greater number of signals coming from different sectors of the economy, the higher the chances are there of financial collapse.

First index combines all the signals of a variable on a time scale, let "X" with the vector of "n" indicators. In any given period, there may be zero or "n" signals. Thus, the first composite indicator I_t^1 is defined as:

$$I_t^1 = \sum_{j=1}^{n} S_t^j \quad (12)$$

where, S_t^j is equal to one if $j(X_t^j)$ crosses the threshold in equation 6 during period "t" and zero otherwise. The number of signals, however, may not be a good composite leading indicator for crises as sometimes

the signals issued can be of very extreme level but it will still be taken as a normal signal. In other words, this statistic will not discriminate between the signals provided by a mild and an extreme unnatural behaviour of a variable. To stretch an example, consider an economic situation where an extreme real appreciation of the domestic currency may signal a future crisis with more accuracy than just a mild appreciation of it. To account for this information, two different thresholds for each variable are defined, X_m^j the mild threshold and X_e^j the extreme threshold. X_t^j will issue a mild signal in period t, $SM_t^j = 1$, when $|X_m^j| < |X_t^j| < |X_e^j|$ where m and e denotes mild and extreme time periods respectively, and extreme signal will be issued and $SE_t^j = 1$ when $|X_e^j| < |X_t^j|$. Thus the second composite indicator, I_t^2 accounts for the intensity of the signal for each univariate indicator. This indicator is defined as:

$$I_t^2 = \sum_{j=1}^{n} \left(SM_t^j + 2SE_t^j \right) \tag{13}$$

Indicator I_t^2 will have twice the weight of mild signal and hence this index can take the value between 0 and $2n$. It is noted in the literature [21] that the above two indicators cannot capture certain situations in the economy. For example, if output collapses in one month following instability, the stock market may sharply decline the following month, and foreign exchange reserves can be depleted within two months' time. Subsequently, exports may decline substantially within three months' time and so on. As a result, it cannot be asserted at the end of last month that the only sign of distress in the economy is the loss of export markets. Instead the overall problems are multiple. To capture the on-going deterioration in fundamentals, the index can be formulated as:

$$I_t^3 = \sum_{j=1}^{n} S_{t-s,t}^j \tag{14}$$

where $S_{t-s,t}^j$ is equal to one if the variable "j" signals at least once in period "t" or in the previous "s" periods and zero otherwise. In this model "s" is equal to eight as suggested in KLR [16].

In addition to the above three indices, the final composite index is defined as the weighted average of the signals of each indicator, where the inverse of noise-to-signal ratio has been applied as weights. Let ωj denotes the noise-to-signal ratio of indicator "j", and then the composite index of "n" indicators is defined as:

$$I_t^4 = \sum_{j=1}^{n} \frac{1}{\omega^j} S_{t,j} \tag{15}$$

Development of all the indices is very crucial in order to generate all the possible information coming from the variables as these indices play a decisive role in realizing the performance of the variables.

EMPIRICAL RESULTS, DISCUSSION AND ANALYSIS

After transforming the data according to the chosen criteria mentioned earlier, the specific thresholds for variables have been generated based on the percentiles of the distribution of variables. After attempting some of the thresholds and observing their performance, 85th percentile is selected as the upper bound to signal distress and 15th percentile as the lower bound to signal a disruption. When it comes to index building and counting for extreme signals, 90th and 10th percentiles are taken as thresholds for respective variables. From these thresholds, the signals have been generated based on the signal extraction matrix given in table 1. From these signals, the good and bad signals have been calculated and noise-to-signal ratio is generated for each variable. Variables with NTSR more than 1 are of no significance and therefore dropped from the study in calculating the probability because variables with NTSR of more than 1 indicates that for a particular variable, there are more bad signals than good signals which is not preferable.

As the study has been carried out in two parts, one being in-sample and another as out-of-sample, the results are also discussed separately for each variable across the country. The performance of the indicators is observed in two parts. Firstly, the performance of the variables in each country is observed and spotted that which variables were significant for a particular country. Subsequently, each variable and its performance in the sample countries is realized which provides the information about the overall performance of a particular variable in the region. In this way, not only overall factors which affected the region can be realized, but country specific reasons can also be captured. Figure 1 highlights the in-sample performance of variables for the Malaysian economy as an example.

As can be seen in figure 1, almost all the variables signalled crisis during the crisis window as all the variables crossed the threshold levels and this performance is satisfactory. Complete details of the behaviour of the variables both in in-sample and out-of-sample is also observed and can be provided upon request as it is not added here due to space limitation. For the variables and their performance from the country' perspective in the in-sample study is provided as follows: for Indonesia; the variables which performed well with low NTSR are, stock price, M2/reserves, interest rate, reserves, non-bank liabilities, M2 multiplier, M2, and exports respectively. Variables which have low NTSR also performed well on the NTSB and Kuipers Score which is positive observation.

In case of Malaysia, the variables which performed well based on low NTSR are: Interest rate, inflation rate, exports, stock price, M2, output, reserves, and bank securities respectively. The variables which scored below one on NTSR, also scored better on

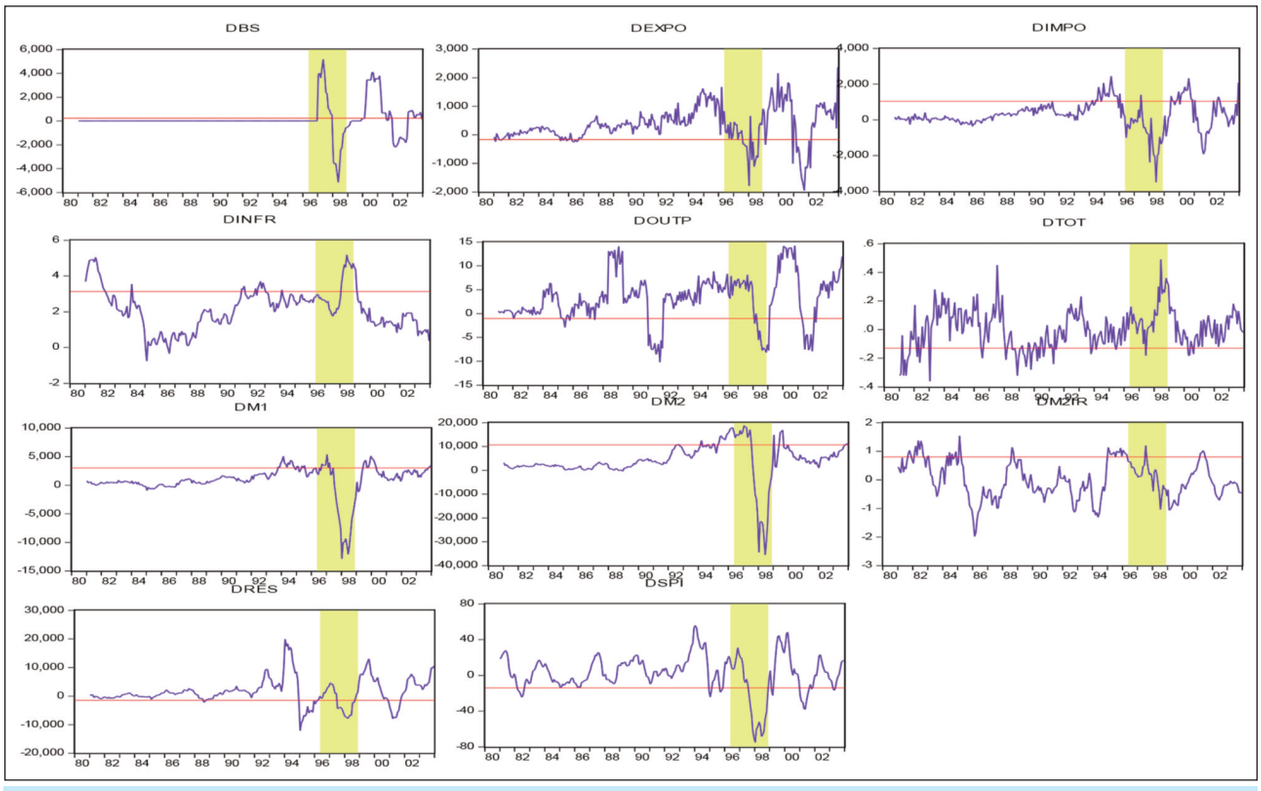

Fig. 1. Variables behaviour (Malaysia)

Kuipers Score. However, the STNB score of these variables is negative except interest rate and inflation rate, which indicates that other variables, generated on average, the more percentage of false alarms as compared to crisis periods correctly called. For the Philippines, the variables which were significant on low NTSR include: Inflation rate, DC/GDP, reserves, M2, M1, and budget deficit/surplus. Inflation rate performed well on both KS and STNB and it correctly called 38% of the crisis. Other variables have negative observation for STNB indicating that these variables generated more false alarms than good signals during crisis period. As of Singapore, indicators performed well during the crisis and variables which were positive during crisis based on low NTSR are: Exports, M2/reserves, exchange rate, reserves, M2 multiplier, Budget deficit/surplus, and terms of trade respectively. All these variables hint to the monetary issues which was the actual problem during that time period. The variable which showed highest significance is exports which correctly called (59%) of the crisis. Variables performance for South-Korea is best in the sample. Variables of significance include: Reserves, interest rate, CA/GDP, inflation rate, M2M, No. of Bankruptcies, output, DC/GDP, M2/reserves, non-Bank liabilities, exports, bank reserves/bank assets, and fiscal balance/GDP. Almost all the significant variables performed well both on STNB and KS with M2M correctly calling 70% and DC/GDP calling (57%) of the crisis. Results for Thailand indicated that variables which proved to be significant on low NTSR are reserves, exchange rate, stock price, inflation rate, exports, and fiscal balance/GDP respectively, with stock price and international reserves performing very well on KS and STNB and correctly calling (84%) and (65%) of the crisis respectively. As Thailand was the major country to be hit by the crisis during AFC and the significance of exchange rate, reserves, and stock prices clearly explain the troubles for this country. Based on the NTSR across the region, i.e. South-East Asia (SEA), the variables which performed better and were highly significant include: reserves, exports, and inflation rate. Most of the variables showed partial significance, i.e. these variables were significant in some countries, but did not show signs of significance in other countries that include: Interest rate, exchange rate, M2/Reserves, M2 multiplier, DC/GDP, fiscal balance/GDP, stock prices, the level of output, and budget deficit/surplus. Remaining other variables proved to be insignificant for the sample countries which indicate that those variables either have nothing to specify during the crisis or had negligible effects (table 2).

The overall analysis of crisis indicators is significant based on all the applied approaches as can be seen from tables 3 and 4 as these variables were successful in highlighting the main symptoms of crisis during the AFC because most of the variables related to AFC were highly significant in the region (e.g. Reserves, exports). Therefore, the satisfactory performance of these variables during the AFC ensures that these variables can perform well within this approach and crises can be detected.

The sample countries were also affected during the GFC, hence, the testing sample (out-of-sample) results can be interesting in a way that whether the

Table 2

SIGNIFICANCE OF VARIABLES ON THE BASIS OF NTSR, NTSB, AND KS FOR THE WHOLE SAMPLE PERIOD												
Indicator	**Indonesia**		**Malaysia**		**Philippines**		**Singapore**		**South Korea**		**Thailand**	
	I.S	**O.S**	**I.S**	**O.S**	**I.S**	**O.S**	**I.S**	**O.S**	**I.S**	**O.S**	**I.S**	**O.S**
International reserves	XZ	XYZ	XZ	XYZ	XZ	XZ	XZ	XYZ	XYZ		XYZ	
Interest rate	XYZ		XYZ			XZ			XYZ	XYZ		
Exports	XZ	XYZ	XZ	XYZ		XYZ	XZ	XYZ	XZ	XYZ	XZ	XYZ
Imports		XYZ		XYZ				XYZ		XYZ		XYZ
Terms of trade		XYZ		XYZ		XYZ	XZ	XYZ				XYZ
Current account of GPD									XYZ			
M1				XYZ	XZ							XYZ
M2	XZ		XZ	XYZ	XZ							
M2/International reserves	XYZ			XYZ			XYZ		XYZ	XZ		
M2 multiplier	XYZ	XYZ					XZ		XYZ	XYZ		
Domestic credit/GDP		XYZ		XYZ	XZ			XYZ	XYZ			XYZ
Domestic real interest rate										XYZ		
Bank deposit				XYZ						XYZ		XYZ
Bank reserves/Bank assets		XYZ		XYZ				XZ	XZ			XYZ
Fiscal balance/GDP				XYZ					XZ	XYZ	XZ	
Output			XZ	XYZ					XYZ	XYZ		
Stock Price	XYZ	XYZ	XZ	XYZ							XYZ	
Oil Price		XZ										
Gold Price												
Inflation rate			XYZ	XYZ	XYZ	XYZ		XYZ	XYZ	XYZ	XYZ	XYZ
Budget deficit-surplus					XZ	XYZ	XZ	XYZ		XYZ		
Non-bank liabilities	XYZ	XZ				XYZ		XZ	XYZ			XYZ
Bank Securities			XZ	XYZ								
No. of bankruptcies												
Lending to Deposit Rate				XYZ		XYZ		XYZ		XYZ		XYZ
Fiscal balance/GDP												

Note: I.S. stands for in-sample and O.S. stands for out-sample data; X, Y, and Z represents the significance of the variables on the bases of NTSR, STNB, and KS.

Table 3

RESULTS OF SIGNALS APPROACH IN-SAMPLE						
Indicator	**Threshold Value**	**Noise to Signal Ratio [B/(B+D)]/ [A/(A+C]**	**Signal to Noise Balance [A/(A+C) – B/(A+C)]**	**Kuipers Score [A/(A+C) – B/(B+D)**	**Conditional Crisis Probability A/(A+B)**	**Percentage pre-crisis periods correctly identified A/(A+C)**
INDONESIA						
International reserves	–708.270	**0.306**	-	0.1789	0.5	25.806
Interest rate	24.9	**0.153**	0.2581	0.4369	0.666	51.612
Exports	–352.5	**0.982**	–0.3548	0.0029	0.238	19.23
Imports	619.82	1.166	–0.5455	–0.0354	0.218	21.212
Terms of trade	–0.291	2.45	–0.2258	–0.0469	0.111	3.225
M1	3525.15	1.17	–0.7097	–0.0390	0.210	25.806
M2	16007.16	**0.532**	–0.3548	0.2264	0.365	48.387
M2/International reserves	4827.114	**0.13**	0.2581	0.3087	0.785	35.483
M2 multiplier	30193200	**0.357**	0.0645	0.1658	0.571	25.806
Fiscal balance/GDP	-	-	–0.5161	–0.1584	-	-
Stock Price	–17.35	**0.092**	0.2258	0.2929	0.769	32.258

Table 3 (*continuation*)

Indicator	Threshold Value	Noise to Signal Ratio [B/(B+D)]/ [A/(A+C]	Signal to Noise Balance [A/(A+C) – B/(A+C)]	Kuipers Score [A/(A+C) – B/(B+D)	Conditional Crisis Probability A/(A+B)	Percentage pre-crisis periods correctly identified A/(A+C)
Inflation rate	5.977	1.091	–0.7419	–0.0265	0.219	29.032
Non-bank liabilities	389.7	**0.306**	0.0000	0.4471	0.5	64.516
Bank Securities	3300	11.66	–1.1935	–0.3440	0.025	3.225
MALAYSIA						
International reserves	–1513.672	**0.548**	–0.3548	0.2041	0.358	45.161
Interest rate	10.289	**0.015**	0.6129	0.6354	0.952	64.516
Exports	–165.344	**0.330**	–0.0323	0.2807	0.481	41.935
Imports	1042.636	12.277	–1.2581	–0.3638	0.024	3.225
Terms of trade	–0.13	2.14	–0.1935	–0.0370	0.071	3.225
M1	3006.84	1.091	–0.7419	–0.0265	0.219	29.032
M2	10688.45	**0.4412**	–0.2258	0.2884	0.410	51.612
M2/International reserves	0.798647	2.915	–0.5484	–0.1236	0.095	6.451
Fiscal balance/GDP	–0.022	3.069	–0.5806	–0.1335	0.05	6.451
Output	–1.017	**0.450**	–0.2308	0.1691	0.363	30.769
Stock Price	–13.906	**0.429**	–0.1935	0.2760	0.416	48.387
Inflation rate	3.129	**0.1705**	0.1290	0.2408	0.642	29.032
Bank securities	226.400	**0.857**	–0.7727	0.0777	0.292	54.545
PHILIPPINES						
International reserves	–789.012	**0.345**	–0.0323	0.1690	0.470	25.806
Exports	–51.642	6.75	–0.6774	–0.1856	0.043	3.225
Imports	418.969	1.168	–0.5405	–0.0455	0.25	27.027
Terms of trade	–0.13	6.138	–0.6129	–0.1658	0.047	3.225
M1	1067.901	**0.908**	–0.4324	0.0296	0.3	32.432
M2	4244.656	**0.497**	–0.1351	0.2444	0.439	48.648
M2 multiplier	0.730	1.402	–0.3514	–0.0543	0.217	13.513
Domestic credit/GDP	0.311	**0.323**	–0.0323	0.3925	0.486	58.064
Bank reserves/						
Bank assets	0.063	9.2	–0.9355	–0.2648	0.032	3.225
Fiscal balance/GDP	–0.015	4.143	–0.8065	–0.2028	0.068	6.451
Inflation rate	5.7	**0.083**	0.2973	0.3468	0.823	37.837
Budget deficit-surplus	–167.910	**0.92**	–0.4516	0.0179	0.25	22.580
Lending to Deposit Rate	1.726	11.68	–0.7838	–0.2888	0.032	2.702
SINGAPORE						
Nominal exchange rate	1.575	**0.426**	–0.2258	0.3331	0.418	58.064
International reserves	573.492	**0.46**	–0.1935	0.2089	0.4	38.709
Exports	–209.206	**0.326**	–0.0323	0.3478	0.484	51.612
Imports	-	-	–1.0270	–0.4000	-	-
Terms of trade	–0.06	**0.997**	–0.2903	0.0003	0.235	12.903
M1	1924.487	12.852	–0.8649	–0.3203	0.029	2.702
M2	8156.652	1.081	–0.4324	–0.0199	0.264	24.324
M2/International reserves	0.091	**0.389**	0.0000	0.0990	0.5	16.216
M2 multiplier	0.48	**0.486**	–0.0811	0.1664	0.444	32.432
Bank Deposits	-	-	–0.5806	–0.1782	-	-
Bank reserves/Bank assets	0.015464953	4.092	–1.1935	–0.2993	0.0698	9.677

Table 3 (*continuation*)

Indicator	Threshold Value	Noise to Signal Ratio [B/(B+D)]/ [A/(A+C]	Signal to Noise Balance [A/(A+C) – B/(A+C)]	Kuipers Score [A/(A+C) – B/(B+D)	Conditional Crisis Probability A/(A+B)	Percentage pre-crisis periods correctly identified A/(A+C)
Inflation Rate		-	–0.2162	–0.0842	-	-
Budget deficit-surplus	–494934.947	**0.708**	–0.5484	0.1223	0.302	41.935
Non-bank liabilities	2.921	3.7	–0.4595	–0.1459	0.095	5.405
Lending to Deposit Rate	3.411	3.738	–1.1622	–0.3701	0.094	13.513
SOUTH-KOREA						
International reserves	–505.4051163	**0.021**	0.4194	0.4417	0.933	45.161
Interest rate	11.5	**0.024**	0.4054	0.4219	0.941	43.243
Exports	–92.2	**0.460**	–0.1935	0.2089	0.4	38.709
Imports	-	-	–1.1081	–0.4316	-	-
Terms of trade	–0.13	2.608	–0.4839	–0.1038	0.105263158	6.451
Current account to GDP	–0.011	**0.027**	0.3226	0.3449	0.916	35.483
M1	6378.252	6.42	–0.8378	–0.2933	0.057	5.405
M2	39226.666	2.804	–0.8378	–0.2438	0.121	13.513
M2/International reserves	3.004	**0.389**	0.0000	0.0165	0.5	2.702
M2 multiplier	1.558	**0.104**	0.5135	0.6290	0.787	70.270
Domestic credit/GDP	0.240	**0.333**	0.0811	0.3781	0.538	56.756
Bank reserves/Bank assets	0.021	**0.552**	–0.2581	0.1444	0.357	32.258
Fiscal balance/GDP	–0.023	**0.726**	–0.0968	0.0529	0.4	19.354
Output	0.66	**0.276**	0.0323	0.2335	0.526	32.258
Inflation rate	4.422	**0.064**	0.2703	0.3033	0.857	32.432
Non-bank liabilities	680	**0.389**	0.0000	0.2145	0.5	35.135
Bank securities	26470	2.077	–0.7027	–0.1747	0.157	16.216
No. of bankruptcies	1202.4	**0.122**	0.3514	0.4504	0.76	51.351
Lending to Deposit Rate	1.305	4.414	–0.8378	–0.2768	0.081	8.108
THAILAND						
International reserves	–158.594	**0.076**	0.4839	0.5957	0.8	64.516
Exports	–51.885	**0.3273**	–0.0323	0.3255	0.483	48.387
Imports	844.256	13.631	–0.9189	–0.3414	0.027	2.702
Terms of Trade	-	-	–0.1935	–0.0594	-	-
Fiscal balance/GDP	–0.01	**0.562**	–0.1613	0.0846	0.352	19.354
Stock Price	–170.009	**0.106**	0.5484	0.7496	0.742	83.870
Inflation rate	3.852	**0.1557**	0.3243	0.4563	0.714285714	54.05405405
Budget deficit-surplus	–577.071	1.074	–0.4839	–0.0144	0.222	19.354
Lending to Deposit Rate	-	-	–1.1351	–0.4421	-	-

Table 4

RESULTS OF SIGNALS APPROACH OUT-SAMPLE						
Indicator	**Threshold Value**	**Noise to Signal Ratio [B/(B+D)]/ [A/(A+C]**	**Signal to Noise Balance [A/(A+C) – B/(A+C)]**	**Kuipers Score [A/(A+C) – B/(B+D)**	**Conditional Crisis Probability A/(A+B)**	**Percentage pre-crisis periods correctly identified A/(A+C)**
INDONESIA						
Nominal exchange rate	-	-	0.0968	0.1041	-	-
International reserves	–2618.57	**0.45**	0.0323	0.1241	0.538	22.580
Interest rate	15.188	2.838	–0.3548	–0.1186	0.133	6.451

Table 4 (*continuation*)

Indicator	Threshold Value	Noise to Signal Ratio [B/(B+D)]/ [A/(A+C]	Signal to Noise Balance [A/(A+C) – B/(A+C)]	Kuipers Score [A/(A+C) – B/(B+D)	Conditional Crisis Probability A/(A+B)	Percentage pre-crisis periods correctly identified A/(A+C)
Exports	–2118.37	**0.084**	0.2581	0.2659	0.9	29.032
Imports	2736.565	**0.147**	0.2903	0.2750	0.909	32.258
Terms of trade	–0.21	**0.354**	0.0968	0.1041	0.714	16.129
M1	13069.22	3.1	–0.2581	–0.1355	0.166	6.451
M2	49858.53	3.1	–0.2581	–0.1355	0.166	6.451
M2/International reserves	7837.612	3.1	–0.2581	–0.1355	0.166	6.451
M2 multiplier	75568750	**0.118**	0.2581	0.2558	0.9	29.032
Domestic credit/GDP	–0.025289	**0.1208**	0.2414	0.2425	0.888	27.586
Domestic real interest rate	-	-	0.2903	0.2750	-	-
Bank reserves/Bank assets	0.041	**0.267**	0.1667	0.1952	0.727	26.666
Fiscal balance/GDP	–0.011	1.765	–0.1429	–0.0820	0.3	10.714
Stock Price	21.6288	**0.0449**	0.3871	0.4005	0.928	41.935
Oil Price	109.256	**0.611**	–0.0645	0.0627	0.416	16.129
Gold Price	-	-	0.2903	0.2750	-	-
Inflation rate	-	-	–0.0476	–0.0476	-	-
Non-bank liabilities	199	**0.977**	–0.0323	0.0044	0.4615	19.3548
Bank securities	7200	4.189	–0.2581	–0.2058	0.166	6.451
Lending to Deposit Rate	-	-	–0.0323	0.0044	-	-
MALAYSIA						
Nominal exchange rate	-	-	0.3871	0.4024	-	-
International reserves	–455.641	**0.040**	0.3871	0.4024	0.909	32.258
Interest rate	6.364	6.112	–0.4194	–0.1649	0.909	32.258
Exports	–2118.37	**0.075**	0.2903	0.2982	0.909	32.258
Imports	1904.575	**0.375**	0.1000	0.1250	0.909	32.258
Terms of trade	–0.05	**0.62**	0.0667	0.0632	0.909	32.258
M1	9856.47	**0.1293**	0.2333	0.2322	0.909	32.258
M2	44073.97	**0.5172**	0.1000	0.0966	0.909	32.258
M2/International reserves	0.490	**0.555**	0.0333	0.0296	0.909	32.258
M2 multiplier	1.551	1.586	–0.1304	–0.0765	0.909	32.258
Domestic credit/GDP	0.017	**0.113**	0.2609	0.2699	0.909	32.258
Bank deposits	44.489	**0.107**	0.2800	0.2855	0.888	32
Bank reserves/Bank assets	0.014	**0.076**	0.2800	0.2956	0.888	32
Fiscal balance/GDP	–0.015	**0.517**	0.1000	0.0966	0.909	32.258
Output	–8.854	**0.115**	0.2759	0.2746	0.909	32.25
Stock Price	–26.89	**0.098**	0.2581	0.2618	0.909	32.258
Inflation rate	4.401	**0.295**	0.1667	0.1644	0.909	32.258
Non-bank liabilities	–461.932	3.039	–0.2258	–0.1973	0.230	9.677
Bank securities	2058.104	**0.273**	0.2258	0.2343	0.769	32.258
No. of bankruptcies	-	-	0.2333	0.2322	-	-
Lending to Deposit Rate	2.271	**0.189**	0.0968	0.1046	0.909	32.258
PHILIPPINES						
Nominal exchange rate	43.151	**0.654**	–0.0968	0.0668	0.4	19.354
International reserves	2523.143	**0.612**	–0.0323	0.0749	0.9	31.034

Table 4 (*continuation*)

Indicator	Threshold Value	Noise to Signal Ratio [B/(B+D)]/ [A/(A+C]	Signal to Noise Balance [A/(A+C) – B/(A+C)]	Kuipers Score [A/(A+C) – B/(B+D)	Conditional Crisis Probability A/(A+B)	Percentage pre-crisis periods correctly identified A/(A+C)
Interest rate	10.1366	**6.112**	–0.4194	–0.1649	0.066	3.225
Exports	–884.952	**0.111**	0.2759	0.2759	0.9	31.034
Imports	806.861	1.206	–0.0357	–0.0296	0.444	14.285
Terms of trade	–0.099	**0.772**	0.0357	0.0406	0.555	17.857
Current account to GDP	0.001	1.631	–0.1935	–0.0611	0.25	9.677
Domestic real interest rate	-	-	–0.3448	–0.2439	-	-
Bank reserves/Bank assets	-	-	–0.8889	–0.1951	-	-
Fiscal balance/GDP	–0.011	1.206	–0.0357	–0.0296	0.444	14.285
Inflation rate	8.794	**0.111**	0.2759	0.2759	0.9	31.034
Budget deficit-surplus	–404.679	**0.125**	0.2581	0.2826	0.833	32.258
Non-bank liabilities	15.530	**0.452**	0.1429	0.2085	0.615	38.095
Lending to Deposit Rate	2.683	**0.070**	0.3103	0.3204	0.909	34.482
SINGAPORE						
Nominal exchange rate	-	-	–0.4839	–0.2113	-	-
International reserves	4965	**0.328**	0.0968	0.1733	0.615	25.806
Exports	–5331.318	**0.229**	0.2258	0.2237	0.818	29.032
Imports	5574.6545	**0.1149**	0.2667	0.2655	0.9	30
Terms of trade	–0.09	**0.258**	0.2000	0.1977	0.8	26.666
M1	17484.858	6.557	–0.3226	–0.1793	0.083	3.225
M2	44440.492	6.557	–0.3226	–0.1793	0.083	3.225
M2/International reserves	0.111	2.068	–0.1000	–0.1069	0.333	10
M2 multiplier	0.932	2.068	–0.1000	–0.1069	0.333	10
Domestic credit/GDP	0.470	**0.114**	0.2667	0.2655	0.9	30
Domestic real interest rate	-	-	–0.3667	–0.2683	-	-
Bank deposits	78.895	1.293	–0.0333	–0.0391	0.444	13.333
Bank reserves/Bank assets	0.014	**0.878**	–0.0333	0.0203	0.454	16.666
Fiscal balance/GDP	–0.01	1.06	–0.0690	–0.0084	0.4	13.793
Inflation rate	6.676	**0.114**	0.2667	0.2655	0.9	30
Budget deficit-surplus	–1150643.906	**0.198**	0.1935	0.2326	0.75	29.032
Non-bank liabilities	3.419	**0.840**	–0.0968	0.0257	0.384	16.129
Lending to Deposit Rate	14.425	**0.068**	0.3226	0.3304	0.916	35.483
SOUTH-KOREA						
Nominal exchange rate	942.2	**0.382**	0.0323	0.1595	0.533333333	25.80645161
International reserves	2262	**0.040**	0.3871	0.4024	0.928	41.935
Interest rate	6.718	**0.058**	0.4194	0.4557	0.882	48.387
Exports	–5428.3	**0.111**	0.2581	0.2581	0.9	29.032
Imports	7291	**0.1336**	0.2258	0.2236	0.888888889	25.806
Terms of trade	–0.08	1.068	0.0000	–0.0089	0.5	12.903
M1	13814.407	7.724	–0.2500	–0.2401	0.111111111	3.571428571
M2	54319.986	7.724	–0.2500	–0.2401	0.111	3.571

Table 4 (*continuation*)

Indicator	Threshold Value	Noise to Signal Ratio [B/(B+D)]/ [A/(A+C]	Signal to Noise Balance [A/(A+C) – B/(A+C)]	Kuipers Score [A/(A+C) – B/(B+D)	Conditional Crisis Probability A/(A+B)	Percentage pre-crisis periods correctly identified A/(A+C)
M2/International reserves	0.303	**0.919**	–0.0500	0.0121	0.428	15
M2 multiplier	0.487	**0.772**	0.0357	0.0406	0.555	17.857
Domestic credit/GDP	–	-	–0.3214	–0.3103	-	-
Domestic real interest rate	0.051	**0.064**	0.3448	0.3549	0.916	37.931
Bank deposits	–655.885	**0.104**	0.2581	0.2600	0.9	29.032
Bank reserves/Bank assets	0.022	6.146	–0.2857	–0.1838	0.1	3.571
Fiscal balance/GDP	–0.009	**0.855**	0.0323	0.0234	0.555	16.129
Output	–3.365	**0.1293**	0.2333	0.2322	0.888888889	26.666
Inflation rate	4.35	**0.2152**	0.2258	0.2278	0.818181818	29.032
Budget deficit-surplus	–23287.008	**0.050**	0.3548	0.3675	0.923	38.709
Bank securities	64000	6.305	–0.3548	–0.1711	0.076923077	3.225806452
No. of bankruptcies	318	2.906	–0.3226	–0.1230	0.142857143	6.451612903
Lending to Deposit Rate	1.572	**0.265**	0.1724	0.2027	0.727	27.586
THAILAND						
Nominal exchange rate	-	-	–0.4839	–0.2113	-	-
International reserves	-	-	–0.4516	–0.2373	-	-
Interest rate	-	-	–0.3871	–0.1690	-	-
Exports	–2252.676	**0.104**	0.2581	0.2600	0.9	29.032
Imports	2775.414	**0.129**	0.2333	0.2322	0.888	26.666
Terms of trade	–0.019	**0.129**	0.2333	0.2322	0.888	26.666
M1	4054.611	**0.1111**	0.2667	0.2667	0.9	30
M2	32112.103	8.275	–0.2333	–0.2425	0.111	3.333
M2/International reserves	-	-	–0.2667	–0.2759	-	-
M2 multiplier	-	-	–0.2667	–0.2759	-	-
Domestic credit/GDP	0.313	**0.208**	0.2258	0.2297	0.818	29.032
Domestic real interest rate	-	-	–0.1333	–0.0976	-	-
Bank deposits	–80.238	**0.295**	0.1667	0.1644	0.777	23.333
Bank reserves/Bank assets	0.039	**0.589**	0.0345	0.0849	0.545	20.689
Fiscal balance/GDP	–0.025	1.295	–0.0333	–0.0391	0.444	13.333
Inflation rate	5.961	**0.5172**	0.1000	0.0966	0.666666667	20
Non-bank liabilities	4500	**0.1751**	0.1935	0.2395	0.75	29.03225806
Bank securities	5127.976	6.83	–0.3871	–0.1881	0.071	3.225
Lending to Deposit Rate	5.5	**0.068**	0.2903	0.3004	0.909	32.258

same set of variables can be able to pick the turbulence during GFC or not? If the results are satisfactory, then it can be concluded that these indicators can perform well and be able to highlight the main causes of crisis and can show the transformation of the crises through their signalling performance under the signal extraction approach.

For out of sample studies, the variables' response has also been observed individually for all sample countries. For Indonesia, significant variables include stock price, exports, M2M, DC/GDP, imports, bank reserves/bank assets, terms of trade, reserves, oil prices, and non-bank liabilities respectively based on their low NTSR. These variables showed a positive

inverse relationship for STNB and KS to NTSR of variables. Maximum percentage of crisis called in the group is by stock price which is (40%). Indicators for Malaysia which have NTSR lower than one, include: Reserves, exports, bank reserves/bank assets, stock price, bank deposits, DC/GDP, output, M1, lending to deposit ratio, bank securities, inflation rate, imports, M2, fiscal balance/GDP, M2/reserves, and terms of trade respectively. Almost all the variables are positive on KS and STNB and maximum no. of crisis called correctly for a variable is (33%) which is on a lower side.

In case of the Philippines, lending/deposit ratio, exports, inflation rate, budget deficit/surplus, non-bank liabilities, reserves, exchange rate, and terms of trade are significant on lower NTSR respectively with lending to deposit ratio correctly calling (35%) of the crisis. Almost all significant variables performed well based on KS and STNB. For Singapore, the variables with significant low NTSR are: Lending/deposit ratio, imports, DC/GDP, inflation rate, budget deficit/surplus, exports, and terms of trade, reserves, non-bank liabilities, and bank reserves/bank assets respectively. Lending to deposit ratio scored maximum and correctly called (36%) of the crisis. All significant variables also performed considerably well on KS and STNB. Indicators for South-Korea, which are significant on the basis of low NTSR are reserves, budget deficit/surplus, interest rate, bank deposits, exports, output, imports, and inflation rate, lending to deposit ratio, exchange rate, M2M, fiscal balance/GDP, and M2/reserves respectively. Interest rate scored better in all areas including STNB and KS and called (49%) of the crisis correctly. In case of Thailand, lending to deposit ratio, exports, M1, imports, terms of trade, non-bank liabilities, DC/GDP, bank deposits, inflation rate, and bank reserves/bank assets are significant with low NTSR respectively. The variable which performed best is lending/deposit ratio and it correctly called (33%) of the crisis. Variables performance on STNB and KS is supportive as almost all significant variables scored positively on both KS and STNB.

Further, when the variables are analysed on the regional basis, the indicators which are significant include: reserves, exports, imports, DC/GDP, bank deposits, bank reserves/bank assets, inflation rate, budget deficit/surplus, non-bank liabilities, lending/deposit rate. Among the variables which were significant for some countries but did not provide significant information for other countries include: Exchange rate, terms of trade, M2/reserves, M2 multiplier, fiscal balance/GDP, output levels, and stock prices. All other variables were mostly insignificant in providing any information with regards to the crisis. In the analysis, variables which are of more significant to notice include DC/GDP, bank deposits, bank reserves/bank assets, and lending to deposit rate ratios. All these variables clearly indicate the banking sector problems which relate to the GFC crisis.

The overall test analysis indicated that variables performance remained significant in out-of-sample study as can be realized from tables 3 and 4. However, the crisis probability to correctly call them was on the lower side which suggested that although this approach can be helpful in understanding and analysing the market situations, it cannot be taken as a sole method to indicate a crisis as asserted by Berg et al. [15]. Another interesting observation to notice is that both KS and STNB proved to be complementary approaches because almost all the variables which were significant based on NTSR also scored positive in both KS and STNB as highlighted in tables 3 and 4.

CONCLUSIONS

As previously asserted, the purpose of the current study is to contribute to the existing literature on financial crises EWS in a way to improve the methods of mapping the turmoil in the financial markets using already existing signals approach with some extension which include, use of broad definition of crisis, different signalling window, additional complementary approaches alongside NTSR and extended dataset. Current study developed an early warning system to identify that which variables tend to indicate that a country might be vulnerable to a financial crisis. In particular, it extended a developed model of KLR [16] and evaluated it based on in-sample performance of the indicators and also the test sample probabilities of crisis. The model proved to be helpful in identifying the turmoil, and this assessment of vulnerabilities can be applied to any individual country or a group of countries over the time.

The performance was mixed for the early warning system as the model generated many false alarms and various indicators did not provide the synthetic vulnerability of a country. However, the model was able to correctly point out the vulnerabilities during crisis periods for different countries such as South-Korea, Malaysia and Thailand. Selected threshold level seems to be playing a major role in signalling false alarms as the number of false alarms were mostly dependent on the threshold used. The lower the threshold chosen, the more signals the model will produce and can generate more noise. However, surging the threshold level reduces the number of wrong signals, but at the expense of missing crises signals. Therefore, it is always very critical to find and apply threshold where the model can produce the least amount of false alarms with optimum crisis signals. The threshold is also very sensitive, as crises are very devastating to the economy and if the model missed the crisis, it can directly cost the economy. However, on the other hand, if the model produced false alarms and indicates an upcoming crisis whereby policy makers take an action based on the model, then it can also cost the economy indirectly as the measures taken by policy makers can be self-destroyer in the absence of a crisis. Moreover, policy makers always have to keep in mind the accuracy of such a system as it is highly likely to be imperfect.

Instead, the goal should be to improve the market performance and the model should be able to address as many shortcomings as possible to help policy-makers in their decision making.

We investigated the effectiveness of signals approach in an early warning system for crises and its impact on textile industry in South-East Asia. Moreover, the dynamics of the textile industry has a significant contribution in achieving a sustainable level of economic growth. Nevertheless, many general conclusions can be drawn from the study: Crises by their nature are uncertain and therefore their exact timing cannot be predicted. Most variables provided early indications but there were many false alarms as well. Among the variables which performed very well during crises include: Reserves, exports, inflation rate, DC/GDP, exchange rate, stock prices, and the level of output. Many of the other variables were significant during one crisis, but did not show any significance during another crisis, which can be explained on the basis that both crises were different in their happenings as AFC was more of currency related crisis, however, GFC was related to banking sector problems and some of the variables which directly relates to banking sector were highly significant during latter crisis that include lending/deposit ratio and bank reserves/bank assets.

For the ability to show the disruptions, the model performance was satisfactory and it did identify the vulnerabilities present within the countries. However, it performed poorly at predicting the crises which is a weak point in the study and suggests refining further the early warning system which might be useful to incorporate additional explanatory variables or to find alternative statistical methods. As a consequence of this a future study can be conducted which include statistical approach as a complementary to this non-parametric approach to be employed as an early warning system to improve the scheme in general even if both approaches can be utilized in tandem to obtain robust solutions with more satisfaction, reliability, and accuracy.

On the other hand, Batool et al. [22] suggested that COVID-19 pandemic outbreak affected the entire economic system. Implicitly, a future direction of research could follow the impact of the Covid-19 crisis on the textile industry in the case of emerging countries. Mehdiabadi et al. [23] highlighted a relevant aspect such as the fact that global economy is constantly changing, which is the main reason for innovation and technological development to contribute in order to achieve sustainable development.

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