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Predicting the Probability of Financial Crisis in Emerging Countries Using an Early Warning System: Artificial Neural Network

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The first upsurge of rising economies in the world took place in early 2000s in Brazil, Russia, India, and China, which are known as BRIC countries. Since then, these countries have demonstrated great investment opportunities for financial services as well as the other real sectors' services. Last decades have witnessed frequent financial disruptions in different kinds which resulted in ruining the economy with unwanted social consequences in BRIC as well as the other countries. The destructive consequences of crisis explain the major reasons for estimating the predicted probability of the crisis. This paper studies the factors associated with the emergence of financial crisis in BRIC countries during 1992-2011 using an Artificial Neural Network. In this context, we built, trained, and tested an Early Warning System (EWS) in order to find out the importance of different inputs in explaining the crisis. So-called model has proven itself by predicting the crisis and non-crisis dates very well. Comparing the importance and significance of all variables in the model, it was discovered that the domestic credit to private sector (% of GDP, domestic credit growth), Inflation, freedom, interest rate and economic growth were the most significant variables in this model, while the deposit insurance rate was found to be the least significant variable in explaining the crisis.

1. Introduction

There have always been constant fluctuations in the volume of economic activities. The financial crisis, a type of economic fluctuation, has been the focus of interest for the economists due to multi-dimensional problems it causes. Financial crisis refers to the

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efficiency loss in financial markets and also imbalance in the financial sector. To define broadly, the sudden and strong changes occurring in price and quantity of financial instruments such as foreign exchanges, stocks, promissory notes, and the bills of exchange are called financial crisis since such changes disrupt the efficiency of financial markets. Foreseeing the financial crises and taking precautions to minimize the length and impacts of the erupted ones are of great importance. Many financial crisis models and theories have been developed to guide the institutions which aim to achieve the goals in question.

The early 2000s witnessed the first wave of rising economies in the world: Brazil, Russia, India and China (BRIC), are also known as first generation of emerging markets. These countries has relatively higher growth rate in both financial and real sectors than the developed nations as well as other developing countries. Financial crises have been threats for these countries trying to meet the requirements of advancements as they distract plans and resources from leading to realizing goals. Therefore, with the introduction of these crises, the motive to gain a better understanding of the probability of emerging financial crisis and the factors explaining such crisis have led to a rapid growth in literature focusing on predicting financial crisis.

The primary purpose of EWS is to detect vulnerabilities that moves an economy towards a crisis, so that preventive policies can be implemented (IMF, working paper, 2010). Hence, such an early warning system is considered as a crucial part of integrated measures taken by authorities to prevent financial crises and facilitate financial stability (Haxhi & Aguilera, 2012). Beginning with the 90s, international organizations started to develop Early Warning System (EWS) models to determine the factors leading the financial crisis. To date, although many investigators dealt with the factors in predicting the crisis, to our knowledge, there has been no specific study on factors explaining the crisis in these countries.

Generally, there have been four perspectives helping the crisis prediction. The first approach belongs to a fundamentalist who emphasized the mismanagement of macro-economy; and the second one to internationalists, who focuses on the international financial markets' inherent volatility, sentiment, self-fulfilling, speculative attack, and contagion. And the third approach is for new fundamentalists, who

underlined regulatory and structural problem, particularly in the financial sector. A fourth approach belongs to the technicalist who mostly focused on the technical finance theory. However, to date, there has been no attempt to make a multilateral perspective for elements or concepts that can help understanding the factors explaining the crisis. Another notable contribution to this paper shows the importance of Freedom index, the index of business freedom, trade freedom, and fiscal freedom, government spending monetary freedom, investment freedom, financial freedom, and property rights.

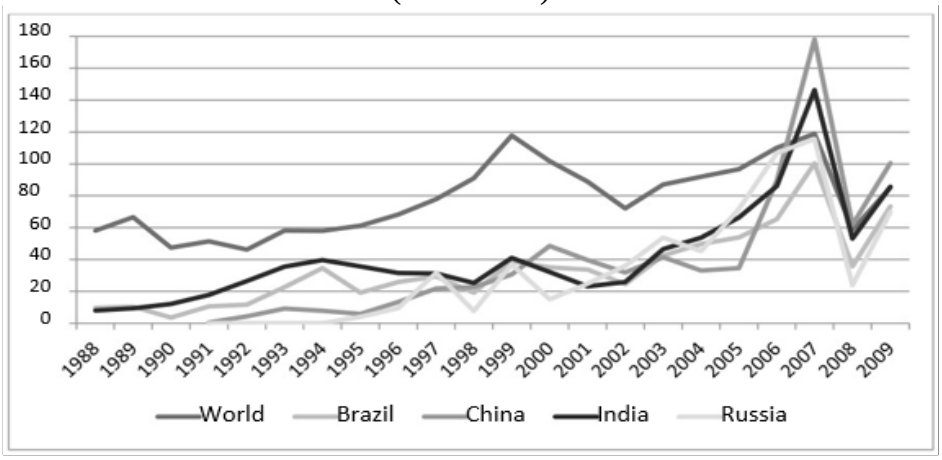
Understanding the importance of factors explaining the crisis helps managers and policymakers adopt preventive strategies against negative repercussions. In this study, the determinants of financial crisis in BRIC countries, from 1992 to 2011, are investigated empirically by making use of the method of Artificial Neural Networks (ANN). This paper hypothesizes that Artificial Neural Network (ANN) along with the index of freedom and the variable of deposit insurance improves the predictability of EWS. The remaining paper is organized in the following sections; Section 2 provides a stylized fact about BRIC countries, Section 3 presents the literature review, Section 4 discusses the empirical results, and section 5 incorporates brief conclusions.

2. Stylised fact about BRIC countries

Over the past few years, rise of emerging markets has been one of the biggest events in the world of investment. Compared to the developed markets, these countries continue to grow at a higher rate in terms of GDP per capita (Based on WDI indicators). Financial sector as a part of economy is also growing more than the World on average. One of the most important indicators for measuring the financial development is market capitalization over GDP. If this ratio increases, it means financial market and especially stock market in this economy will become more developed. The trend of market capitalization over GDP in BRIC is depicted in figure 1, as shown in this figure, although this ratio was significantly smaller than the average of the world for a quite long period of time, this ratio had an increasing trend in BRIC countries to the stage that so-called ratio in China and India exceeded the average level of the world in 2007 and thereafter. This trend

indicates that investment in BRIC economics is becoming more attractive.

Figure 1.1: Trend of market capitalization over GDP in BRICs (1988-2009)



Source: World Development Indicator, World Bank (2011)

Chinese and Indian economies demonstrated an annual growth of 10.0% and 6.5%, respectively, in terms of GDP since 1990 to 2011. By comparison, The World on average grew on an average annual rate of 2.7%; OECD countries grew on an average annual rate of 2%, over the same period. With this rate of growth, Chinese economy witnesses a double growth every seven years and Indian economy observes a double growth every 11 years. As emerging economies tend to grow, they will depict a larger influence over the global economy. Cheng, (2007) estimated that emerging economies will stand for 50% of global GDP by 2050.

3. Literature Review

In this section, different types of financial crisis; different views on factors explaining crisis; and Econometric approaches to identify the determinants of financial crisis are discussed.

3.1. Different Types of Financial Crisis

To date, many studies have been conducted to explain the reasons behind financial crisis that erupted in different regions. The literature

generally covers three types of crises: currency crises, banking crises, and sudden stop crisis.

Currency crisis

The first generation of currency crisis model focuses on the fundamental disequilibrium such as budget deficit, decreasing reserves and growth rate of money supply as a cause of the currency crises (Krugman, 1979). The second generation model shows that a speculative attack could be self-fulfilling if a government is in the vulnerable zone fundamentally unpredictable and therefor anticipating crises is extremely difficult (Kaminsky, 1999).

According to the IMF (1998), a currency crisis occurs when a speculative attack on a currencyresults in a devaluation (or sharp depreciation) of the currency, or forces the authorities to defend the currency by expanding large volumes of international reserves or by sharply raising interest rates. A currency crisis is defined as a situation in which an attack on the currency leads to its sharp depreciation, a large decline in international reserves, or a combination of the two.

Banking crisis

A banking crisis is a situation in which an actual or potential bank runs or failures induce banks to suspend the internal convertibility of their liabilities or which compels the government to intervene to prevent this by extending assistance on a large scale (IMF, 1998). Literature on banking crises focuses on theory of bank runs and bank insolvency (Ivashina, V., David Scharfstein, D., 2010).

In terms of indicators of banking crises, some studies also use EWS models to assess the potential indicators. Goldstein, (2000) studies a sample of 87 currency crises and 29 banking crises that occurred in 25 emerging market economics and smaller industrial countries over 1970-1995, following the work by Kaminsky, (1999) , the signal approach is used to analyse the performance of indicators of currency and banking crises, nine other indicators are added to the existing15 indicators in Kaminsky, (1999).

In terms of indicators of banking crises, there are indicators such as the current account balance, short term capital inflows, foreign direct investment, the overall budget deficits, general government consumption, central bank credit to the public sector and net credit to the public sector.

The first four indicators are expressed as a share of GDP, their finding suggest that, among the banking crisis indicators, the best performing indicators are appreciation of the real exchange rate, a decline in stock prices, a fall in exports, a rise in the M2 multiplier, a fall in output, a rise in real interest rate on bank deposit, a high ratio of short term capital inflows to GDP, and a ratio of current account deficit to investment.

Sudden stop crisis

The currency and banking crisis models focus on macroeconomic policy. However, recent crises in emerging market economies have drawn attention to problems in financial sector and the behaviour of international capital markets. Chang & Velasco, (2000) emphasize the role of financial sector fragility in association with international illiquidity in causing crises. Many crisis-hit countries suffered from liquidity problems. They had high short term debt especially external debt relative to liquid problems. They had high short term debt especially external debt relative to liquid assets or international reserves, and therefor were extremely vulnerable to a reversal capital inflows or sudden stops.

Calvo, (2002) explains that being closed implies a sharp increase in the real exchange rate (depreciation) following the sudden stop. Sharp increases in the real exchange rate deteriorate highly dollarized balance sheets of both public and private sector since highly dollarized liabilities imply larger currency mismatches when the real exchange rate rises. The findings highlight the importance of balance sheet effect in causing sudden stop.

3.2 Different views on factors explaining crisis

Generally, there are four views about the factors which are affecting or making structure of return. First view belongs to fundamentalist who emphasized macroeconomic factors such as interest rates, money

supply, exchange rates, oil and stock prices, inflation, gold price, industrial production, and foreign portfolio investment. The view which focuses on the inherent volatility of international financial markets, sentiment, self-fulfilling speculative attack, and contagion belongs to Internationalist. New fundamentalist emphasize on underlining regulatory and structural problems, particularly in financial sector. The Technicalists are more focused on the technical finance theory. The basic principle of technical analysis is that market price reflects all relevant information. There are two types of investors: news watchers or informed investors and technical or noise traders who use immediate past price information to make investment decisions. Technical analysis uses past price and volume information to forecast the direction of the market. Technical analysts, sometimes called "chartists", may employ models and trading rules based on price and volume transformations, such as the relative strength index, moving averages, regressions, inter market and intra-market price correlations, cycles ,or classically, through recognition of chart patterns.

3.3. Econometric approaches to identify the determinants of financial crisis

There are generally four types of financial analysis and models to develop an Early Warning System. This include :I) structural model, II) Signal approach, III) pooled panel data such as Logit and Probit models, and IV), Artificial intelligence machine learning methods. Among the family of first three approaches, logistic analysis has been widely used for previous crisis prediction studies ,but its reliability is questionable when the assumptions associated with probability models, such as a specific function relationship between dependent variables and independent variables; do not hold (Luther, 1998) and (Zhang, Y. Hu, Eddy Patuwo, & C. Indro,1999). However, ANNs are a promising alternative tool because, in most cases, it is robust and able to adapt itself to the given conditions in order to learn the relationships (Denton, 1990). The most important difference between the ANN and regression models is the method in which the values for the weights are established. ANNs employ a dynamic programming approach to iteratively adjust the weights until the error is minimized while the regression models compute the weights using a mathematical technique

that minimizes the squared error. There is no standard rule for choosing of neural network topology in different types, including Multilayer Perception, Modular Network, Jordan/Elman Network, Time-Lag Recurrent Network, and etc. The most common neural network model is the multilayer perception, or perceptron (MLP).

ANN includes input variables (predictors), output variable (crisis dummy), and training algorithm. The process is implemented in three stages, the first-stage (model-building) with 70 percent of data, the second-stage (training and validation) with 15 percent of data, and the third-stage (testing) with 15 percent of data. Following the model-building stage based on the previous literature and the contribution of this paper, the learning stage will be conducted to train the network using Levenberg-Marquardt (TrainLM) optimization. TrainLM is usually the fastest backpropagation algorithm which updates weights, iteratively. Subsequently, each iteration will be evaluated by the validation data. The testing stage will be performed to ensure the generality of the learned model in terms of new data. The applied software (Matlab, SPSS) will produce a number of statistical information at the end of the training, validation, and test stage, which will determine the characteristics of our model.

While the probability of crises is estimated using ANN, the relative importance of each input (predictor) is also analysed in ANN. Particularly, this study proceeds with analysing the importance of predictors in determining the neural network. The analysis is conducted by using both training and testing samples to create a table demonstrating the relative importance and normalized importance for each predictor. Normalized importance is the ratio of the importance values to the largest importance values as reported in percentages.

4. Empirical Analysis

In this study, crisis considered as the dependent variable. It takes the value one for the first year of the financial crisis and zero otherwise. Financial crisis is considered if two of the following conditions are met: I), significant signs of financial distress in the banking system (as indicated by significant bank runs, losses in the banking system, and/or bank liquidations); II) significant banking policy intervention measures in response to significant losses in the banking system. We consider the

first year that both criteria are met to be the year when the crisis occurs. We consider policy interventions in the banking sector to be significant if at least three out of the following seven measures have been used: I) extensive liquidity support; II), 5 percent of deposits and liabilities to non-residents); III), bank restructuring gross costs (at least 3 percent of GDP); IV), significant bank nationalizations; V), significant guarantees take place; VI), significant asset purchases (at least 5 percent of GDP); and vii), deposit freezes and/or bank holidays. The period covered is 1992-2011, with 4 countries, including Brazil, India, Russia, and China; and up to 12 crisis occurrences in the sample.

In this analysis, we want to explain the crisis index "crisis" by a set of independent variables (See Table 1). Many studies choose between the following set of indicators. In this study we followed Neal and Davis, (2005) in choosing the explained variables. However, we added the extra variables as highlighted with a star letter in Table 1. We took the exogenous variable "FDI over GDP" from Demirgüç-Kunt, Detragiache, & Romero, (1997), Demiriguc_kunt, (2005) while we added the other variable (Freedom) which is one of the contributions of our study. It is an index of business freedom, trade freedom, fiscal freedom, government spending monetary freedom, investment freedom, financial freedom, property rights freedom from corruption, and labour freedom. We used annual data covering the period from 1992 to 2011. All the data are obtained from the World Development Indicators (WDI) except for "Crisis" and "Freedom" indices. "Freedom" index is taken from the heritage foundation while the data on crisis is taken from Laeven & Valencia, (2013).

Table 1: Independent variables

Variable name	Definition	Source
GDP growth	Rate of growth of real GDP	WDI
TOT change	Change in the terms of trade	WDI
Real interest	Nominal interest rate minus the contemporaneous rate of inflation	WDI
Inflation	Rate of change of GDP deflator	WDI
M2/Reserves	Ratio of M2 to international reserves	WDI
Credit growth	Rate of growth of real domestic credit to the private sector	WDI
P-Credit /GDP	Ratio of private credit to GDP	WDI
GDP/CAP	Real GDP per capita	WDI
Deposit-ins	Dummy that equals one if the country has explicit deposit insurance (including blanket guarantees) and zero otherwise for	WDI
*FDI/GDP	Foreign direct investment over GDP	WDI
*Freedom	The index of business freedom, trade freedom, fiscal freedom, government spending monetary freedom, Investment freedom, financial freedom, property rights freedom from corruption, labor freedom	The heritage foundation

In order to estimate the probability of a crisis, the most common neural network known as multilayer perception or perceptron (MLP) is employed. We go through three stages while modelling the artificial neural network. The model is built in the first stage, trained in the second stage and tested in the third stage.

Table 2 tabulates the actual results versus predicted probability of crisis by the Back Propagation looking forward ANN approach, for the period from 1992 to 2011 in BRIC's countries. The results show how successfully the net learnt the relationship and predicted the actual output values. In the table below are the actual and predicted values of the output, crisis. As seen, the model predicted the actual values of pressure index at crisis dates very closely. On the other hand, the values of the crisis index at non-crisis dates are also predicted very closely to actual values of crisis index. Therefore, we could infer that the model learnt and predicted the crisis and non-crisis dates very well.

Table 2: Actual versus predicted results of trained net

Country	Time	Predict	Actual
Brazil	1992	NaN	0
	1993	NaN	1
	1994	NaN	1
	1995	1.00E+00	1
	1996	1.00E+00	1
	1997	9.97E-01	1
	1998	5.17E-03	0
	1999	7.53E-06	0
	2000	6.11E-06	0
	2001	1.05E-09	0
	2002	1.58E-10	0
	2003	8.44E-15	0
	2004	1.67E-16	0
	2005	0.00E+00	0
	2006	2.55E-15	0
	2007	2.70E-04	0
	2008	3.65E-07	0
	2009	1.11E-09	0
	2010	2.25E-10	0
	2011	1.29E-04	0
China	1992	NaN	0
	1993	NaN	0
	1994	NaN	0
	1995	1.71E-05	0
	1996	2.92E-02	0
	1997	9.88E-01	1
	1998	1.47E-02	0
	1999	6.82E-10	0
	2000	1.51E-12	0
	2001	3.54E-11	0
	2002	5.05E-10	0
	2003	5.00E-11	0
	2004	7.02E-12	0
	2005	2.24E-03	0
	2006	1.87E-03	0
	2007	2.05E-04	0
	2008	5.60E-10	0
	2009	9.76E-10	0
	2010	2.38E-06	0
	2011	1.25E-09	0

Table 2: Continued: Actual versus predicted results of trained net

Country	Time	Predict	Actual
India	1992	NaN	1
	1993	NaN	0
	1994	NaN	0
	1995	1.72E-15	0
	1996	1.17E-15	0
	1997	8.33E-16	0
	1998	2.33E-15	0
	1999	2.05E-15	0
	2000	2.16E-15	0
	2001	3.76E-14	0
	2002	9.21E-15	0
	2003	5.50E-15	0
	2004	1.50E-15	0
	2005	2.05E-15	0
	2006	1.39E-13	0
	2007	3.16E-13	0
	2008	1.51E-05	0
	2009	6.97E-10	0
	2010	8.33E-15	0
	2011	4.40E-14	0
Russia	1992	NaN	0
	1993	NaN	0
	1994	NaN	0
	1995	1.26E-03	0
	1996	3.86E-03	0
	1997	9.94E-01	1
	1998	1.41E-03	0
	1999	2.79E-09	0
	2000	3.86E-12	0
	2001	2.47E-12	0
	2002	7.40E-11	0
	2003	2.54E-08	0
	2004	1.91E-09	0
	2005	8.35E-11	0
	2006	1.79E-06	0
	2007	9.97E-01	1
	2008	1.00E+00	1
	2009	1.00E+00	1
	2010	9.99E-01	1
	2011	2.17E-06	0

Note: Not A Number (NAN) cells referred to not applicable cells. NAN refers to the unpredicted probability of crisis due to missing values in the variable of Freedom.

The relative importance of inputs is an indicator of how significant each of the inputs in the predictive model is. The values of this parameter range from 0 to 1. Higher values are associated with more important inputs. If the importance value of input is zero, that input considered useless and might be omitted. We should pay attention to the following warnings while evaluating the importance values of the inputs. Firstly, we cannot assume that input 1 is twice as good as input 2, i.e., if the importance value of input 1 is 0.2 and the importance value of input 2 is 0.1. All we can say with confidence is that input 1 is more important than input 2. Secondly, the sum of the importance values of all inputs is approximately 1. Therefore, these importance values may be thought of as the percent contribution to the model of each variable. The importance of each variable in the predictive model is shown by table as follows:

Table 3: Relative importance of inputs

Variables	**Importance**	**Normalized Importance**
Domestic credit to private sector (% Of GDP)	.104	100.0%
Fiscal surplus (deficit)	.083	80.6%
GDP growth (%)	.090	87.3%
GDP per capita real (growth %)	.081	78.0%
Change of trade	.070	67.9%
Real interest rate	.092	88.9%
Inflation (growth of GDP deflator)	.098	94.8%
Domestic credit (growth)	.099	95.7%
Deposit insurance	.017	16.3%
Freedom	.093	89.6%
FDI/GDP%	.087	83.8%
M2/International reserve	.085	82.5%

Source: Author's Estimate

As can be observed from the table, the most important input in predicting the output is the input of Domestic credit to private sector (% Of GDP) because its value of importance is the greatest. On the other hand, the input which is the least important in predicting the output is the input of Deposit insurance since its value of importance is the smallest of all.

5. Concluding Remarks

This global economic and financial instability in 1990s and 2000s had a widespread effect on the world economy and especially on some countries such as BRIC's countries which are more investment-attractive. These crises led to a large discussion on the theoretical aspect of the crisis models, and also influenced on empirical analyses that aimed at identifying the leading variables explaining the crisis. Prediction of recession is an important task because policymakers would like to anticipate future recessions so that they have enough time for remedial policy actions to oppose them. In our study, for the period covering 1992 to 2011, financial crises that erupted in BRIC's countries analysed by making use of the method of Artificial Neural Network (ANN) . For this purpose an ANN model is built, trained and tested to provide predictions for the probability of financial crises and to find out major factors explaining the probability of crisis. As a result, we have a better understanding of how the probability of occurring financial crisis influenced by a host of factors, including change in the term of trade, real interest rate, inflation, ratio of M2 to international reserves, credit growth, ratio of private credit to GDP, real GDP per capita, insurance deposit, the ratio of foreign direct investment over GDP, and freedom. Comparing the actual and predicting probability of crisis, we could infer that the model learnt and predicted the crisis and non-crisis dates very well. Further, considering the importance and significance of all variables in the model, it is demonstrated that the variable of Insurance Deposit rate was the least significant variable, while the variable of domestic credit to private sector (% Of GDP) was found out to be the most significant variable in the model. Further studies are warranted to predict the recession using the built model in this study.

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