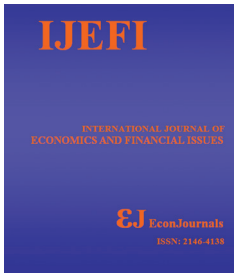

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Early Detection of Indonesia's Vulnerability to Currency Crisis

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ABSTRACT

This study addresses an early warning system (EWS) of currency crisis, as well as proposes EWS with an approach of early detection of vulnerability to crisis. Detecting vulnerabilities is a more effective step because it gives the policymakers plenty of time before determining the right policy responses to anticipate and prevent a crisis. The data used are monthly macroeconomic data from January 2002 to December 2012. The steps taken were to identify currency crises, determine indicators of currency crises, determine vulnerability indicators to currency crises with logistic regression, and build vulnerability index to currency crises with fuzzy logic. This research builds vulnerability index to currency crisis with vulnerability level consisting of normal, alert, standby, and crisis suspected condition. This research provides EWS with the approach of early detection of vulnerability to currency crisis and builds vulnerability index that can be used in assessing and monitoring economic condition.

Keywords: Currency Crisis, Early Warning System, Vulnerability
JEL Classifications: G01, C49

1. INTRODUCTION

The global economy is increasingly showing uncertainty. Not even a single country in this world is immune to the threat called economic crisis. This condition causes countries to be vulnerable to crisis. Indonesia, which has experienced two times currency crisis; in 1997 and 2008, remains vulnerable to such crisis. The Asian crisis in 1997 forced Indonesian government to spend enormous budget in order to rescue banks and handle the currency crisis. In 2008, Indonesia experienced another currency crisis that caused the government to issue stimulus to boost the economy.

Basically, the crisis did not occur all of a sudden, but gradually and with signals. The crisis threat can be detected through the changes in economic indicators, which then will give early warning. Therefore, an early warning system (EWS) is essential to anticipate and prevent the occurrence of crisis.

EWS research on crisis has been developed since the 1990s when many regions of the world were increasingly hit by crisis, especially after the Asian one. In general, EWS research aims to anticipate and prevent crisis by predicting its emergence. Kaminsky et al. (1998) predict the possibility of a crisis within the next 24 months using a signal approach. The study looks for key indicators of the currency crisis aimed at building an EWS. Then EWS research continues to be developed in search of the best method to predict the coming crisis. Chin-Shien et al. (2008) predict exchange rate crisis events and compare several methods that have the highest predictive accuracy rate. These EWS studies that attempt to predict the crisis have a major weakness that is often low and inaccurate predictive power. This EWS model still often produces an imperfect crisis prediction because it produces false signals that predict a crisis that does not occur and cannot predict the crisis.

In reality, it is very difficult to predict the crisis appropriately. According to IMF (1998), it is impossible to predict the crisis properly. Although we have built predictive models to influence the behavior of decision makers and financial market agents, the model can quickly become obsolete. It is then more important to identify the types of weaknesses that specifically make the economy vulnerable to financial crises. Also, according to Ghosh et al. (2009), specific events that trigger a crisis cannot be predicted so that with such crisis and uncertainty risk, it is still difficult to convince the

policymakers to take precautions. Both the IMF and Ghosh argue that the early warning efforts should be directed more towards identifying the types of underlying weaknesses or vulnerabilities and then adopting policies to address these vulnerabilities. Meanwhile, the IMF (2010) has made efforts to identify vulnerabilities as contained in the early warning exercise (EWE). The research and the exercises conducted do not aim to predict the crisis. The main purpose of EWE is to identify the underlying vulnerabilities and possible future risks that can trigger the system to a crisis.

Compare to early detection attempts to predict the timing of the crisis, it seems that economies need more early detection of vulnerability to crises. Therefore, more research is needed to detect vulnerability to crisis. Detecting vulnerability is a much more effective measurement because it gives policymakers a lot of time to decide on the right policy responses to prevent a crisis. The level of vulnerability can serve as a signal of crisis. If the level of vulnerability to crises is known, then anticipatory and preventive action will be easily taken by the monetary and financial authorities of a country.

This study aims to detect vulnerability of Indonesia to exchange rate crisis early. Vulnerability is categorized into several levels. The degree of vulnerability is obtained from the vulnerability index. To get the vulnerability index, the elements that construct the vulnerability index; indicators of currency crisis and indicators of currency crisis vulnerability, must be known in advance. The currency crisis can be identified using the exchange market pressure index (EMPI), so that EMPI serves as an indicator of the crisis. The vulnerability indicator is obtained by using logistic regression. The various factors causing the currency crisis were tested to find out the significant variables which instigated the crisis with high prediction accuracy. This significant variable is an indicator of vulnerability. The vulnerability index can be obtained by using fuzzy logic. The vulnerability level consists of normal, alert, standby, or crisis suspected conditions. Assessing vulnerability in this way can provide more effective information in determining the policy responses to be taken.

This paper is structured as follows: Section 2 is a literature review, Section 3 describes the research methodology, Section 4 describes and analyzes the results, and finally Section 5 provides conclusions and suggestions for further research.

2. LITERATURE REVIEW

2.1. The Existing Approach

The existing and emerging EWS research is an approach that attempts to predict the occurrence of a crisis. The method or approach used varies. There are groupings based on parametric and nonparametric methods, such as in Comelli (2013). He compared the predicted results of the crisis using both parametric methods (i.e., regression-based) and non-parametric (i.e., signal-based extraction). There are also groupings of EWS based on signaling-based methods, regression-based methods, methods that use artificial intelligence, hybrid methods that combine two or more methods, and some other. The research with the signal method was developed by Kaminsky et al. (1998).

There are also regression-based methods such as logit and probit regression. This method was used by Frankel and Rose (1996) who predicted the crisis using logit regression. Ari (2012) also used multivariate logit to predict currency crisis in Turkey. Then Comelli (2014) compares the performance of logit (fixed effects) and EWS probit in correctly predicting the currency crisis in selected emerging market economies. Research using artificial neural network predicted the financial crisis in Turkey by Turk (2011). Then Chin-Shien et al. (2008) used the neuro-fuzzy model approach in predicting the incidence of currency crises and also in comparing several methods to find out which method had the highest predicted accuracy. The hybrid method that combines regression and signal methods was used by Ito and Orii (2009) to predict the currency crisis. Another method that can also be used is the method of markov switching. This method was used by Abiad (2003) in predicting the Asian crisis. Cerra and Saxena (2000) also used markov switching in predicting the crisis in Indonesia and the spread of the Asian crisis.

In fact, approach that predicts the occurrence of a crisis has many weaknesses and it is difficult to predict the crisis appropriately. Moreover, it also often generates false signals. Another disadvantage is that the prediction model is also inadequate to be a consideration for policymakers as it may soon become obsolete and incompatible with existing conditions.

2.2. The Proposed Approach

The proposed EWS is an approach that detects the vulnerability to crises. Detecting the vulnerability means looking at changes in the economic indicators, analyzing those changes, and giving the policymakers plenty of time before determining the right policy responses to anticipate and prevent a crisis. Therefore, detecting the vulnerability is a more effective step than predicting a crisis. Thus, through early detection of vulnerability, potential crises can be recognized and prevented from the outset.

The vulnerability detection approach builds the vulnerability indexes and assesses the level of vulnerability. The vulnerability index can be obtained by using fuzzy logic method. As a tool of artificial intelligence, the fuzzy logic has many functions. One of its functions is to classify a condition that can be combined with human knowledge for decision making, so that it can be used to obtain the level of vulnerability. The fuzzy logic assesses and formulates the pressure level. The vulnerability index is aimed at capturing the vulnerabilities and the triggers of the crisis, but this is not the tool for predicting timings and types of crises. The quantitative indicators are completed with qualitative information so that the assessment process becomes more comprehensive. Based on the vulnerability index, an assessment of the potential vulnerability to exchange rate instability is made. The fuzzy logic has the ability to build the vulnerability indices that can provide an assessment of the vulnerability in form of language. Assessing vulnerabilities in this way can provide more effective information to determine the policy taken.

2.3. Currency Crisis Identification

The currency crisis occurs when a speculative attack on the exchange rate causes a sharp exchange rate depreciation, or

when the monetary authority must maintain the exchange rate by releasing large amounts of foreign exchange or by raising the interest rate sharply. The exchange rate crisis can be identified if there is effort to devaluate the exchange rate.

Frankel and Rose (1996) identified the currency crisis simply by defining currency crashes as a nominal exchange rate depreciation of at least 25% and a nominal depreciation increase in the prior year of at least 10%. While Eichengreen et al. (1996) used an alternative approach; by constructing a speculative pressure index. The IMF (1998) argued that crises can be identified using an index that includes not only during significant currency depreciation, but also when the authority's action avoids large devaluations or leaves the pegged exchange rate.

This study identifies the currency crisis through EMPI. Crisis is defined as a condition where there is a very high exchange rate depreciation. EMPI is then used based on this definition. Use of EMPI to identify exchange rate crises is driven by the fact that EMPI reflects exchange rate changes (Δe/e) and reserve change rates (ΔR/R) that can capture changes in exchange rates; depreciated or appreciated, and changes in reserves, where reserves can be used to stabilize the exchange rate. The conditions in which EMPI is equal to or more than a certain threshold is categorized as a period of crisis or high pressure.

2.4. Crisis Indicator

The EMPI serves as an indicator of the crisis. Kaminsky and Carmen (1999) develop an exchange market pressure (EMP) model to calculate the index of currency market turbulence. Establishment of EMP is based on leading indicator of currency crisis. There are various models of exchange market pressure indices. Some use exchange rate and foreign exchange variables, and others use exchange rate, foreign exchange and interest rates, each with their own reasons and considerations.

Frankel and Saravelos (2012) find that both international reserves and real exchange rates are very significant as early warning indicators. This is in line with the Weymark EMP concept that uses international reserve variables and exchange rates in calculating pressure on the exchange market.

The concept of EMP was first introduced by Girton and Roper. Girton and Roper (1977) use a monetary approach in formulating EMP. The independent variables are exchange rate and foreign exchange reserves. Girton and Roper use the term EMP referring to the magnitude of the money market imbalance that can be eliminated through changes in foreign exchange reserves or exchange rates. This theory was later on developed by Weymark (1995). Basically, the EMP aims to analyze the conditions of pressure on the exchange market. EMP is defined as an imbalance in the exchange rate market reflected in exchange rate changes and foreign exchange reserves. Such imbalances can arise from the excess supply of money, thus causing the currency to depreciate, foreign exchange reserves to reduce, and foreign exchange market to be under pressure.

2.5. Vulnerability Indicator

Indicators of vulnerability to the currency crisis stem from the factors leading to a significant currency crisis in predicting the crisis. The vulnerability indicator can be identified from the behavior of a number of macroeconomic and financial variables when a currency crisis occurs. Frankel and Rose (1996) argue that the usual approach used to build an EWS is to identify a set of variables that have different behaviors in episodes of financial market pressures from normal or quiet periods. Then by monitoring these variables, it is possible to detect similar patterns of behavior in the past that preceded the crisis. The difficulty lies in identifying the relevant variables to be monitored; the ones that warn about future crises, but rarely give false signals. Meanwhile, according to the IMF (1998), there are a number of potential variables that are useful as indicators of vulnerability. Choice is broadly defined by an understanding of the causes and approaches of crisis determinants.

IMF (1998) conducted research on early warning signal of vulnerability. They use real exchange rate appreciation, real domestic credit growth, and M2 ratios of international reserves to establish macroeconomic vulnerability indexes against exchange rate crises for six Asian countries and four Latin American countries. The results showed that some countries signaled vulnerability, but some did not. According to them, this showed that there were still other indicators that needed to be monitored, but not yet included in the index.

According to the IMF (1998), there was no single index that might capture the complexity of the development leading to crisis, so it is necessary to recognize the complexity of the causes of the financial crisis and not to depend on a single indicator. Therefore, vulnerability indicators need to be supplemented with country-specific information in order to make decisions based on actual vulnerability to currency crisis of the related country.

Frankel and Saravelos (2012) conducted research on 83 papers and collected leading indicators categorized by Kaminsky and Carmen (1998), Hawkins and Klau (2000), Abiad (2003), and others. Their results show that international reserves, real exchange rates, credit growth rates, gross domestic product (GDP), and current account are indicators that are very often statistically significant in various studies, so they can be used to assess a country's vulnerability to currency crises. Special international reserves and real exchange rates are two very important indicators because they are statistically significant as determinants of crisis in more than half of those 83 papers. Variables can be used as indicators of vulnerability. However, availability of the monthly data also determines the selection of these variables.

2.6. Fuzzy Logic and Vulnerability Index

This study aims to build vulnerability index along with vulnerability level. To achieve these objectives, fuzzy logic method will be used concerning its flexibility and ability to adapt to changes and uncertainties that accompany the problem. As a tool of artificial intelligence, fuzzy logic has many functions. One of the functions is the ability to classify a condition and that it can be combined with human knowledge in decision making, so it can be used to obtain the level of vulnerability. Another advantage of fuzzy logic is its ability in the process of linguistic reasoning.

The vulnerability index is aimed at capturing vulnerabilities and crisis trigger factors, but it is not the tool for predicting timings and

types of crises. The quantitative indicators are complemented by qualitative information so that the assessment process becomes more comprehensive. Based on the vulnerability index, an assessment of the potential vulnerability to exchange rate instability is made.

The fuzzy logic process lies in fuzzy inference system (FIS). FIS is a computational framework based on the concept of fuzzy set theory, IF-THEN fuzzy rules, and fuzzy reasoning. The process of fuzzy inference can be seen in FIS block diagram (Jang et al., 1997) as follows:

The FIS accepts input. If the input is a crisp value, then fuzzy fication must be done first. If the input is in the form of a fuzzy value, then no fuzzy fication process is needed as it could directly be sent to the knowledge base containing *r* fuzzy rules in the form of IF-THEN. If the number of rules is more than one, then all rules will be aggregated. Afterwards, the result of aggregation will be defuzzied to get crisp value as the output.

3. METHODOLOGY

Based on the conceptual framework, this research builds a vulnerability index that can provide information on the level of vulnerability (Figures 1 and 2).

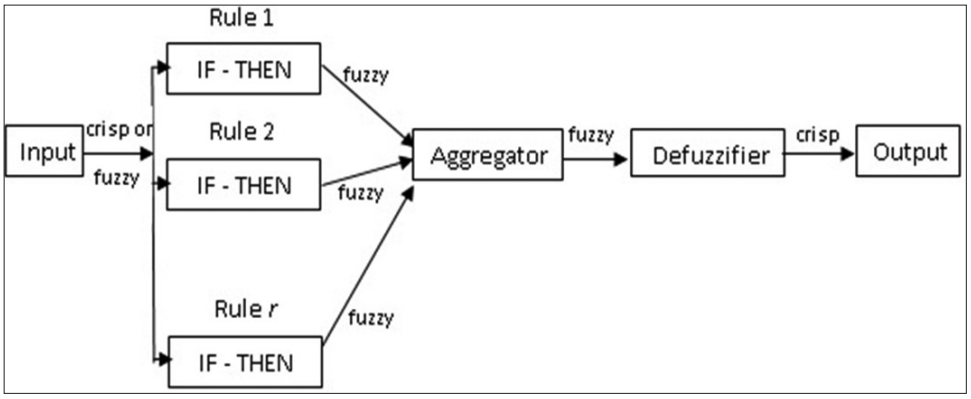
The steps taken in this study to obtain vulnerability index are as follows: Calculating the EMPI which is an indicator of currency crisis, then assessing the ability to predict the crisis of the factors that cause the crisis. Calculation with logistic regression model will give result of significant variable and prediction ability. Explanatory variables that have significant influence and high prediction accuracy will be used as vulnerability indicators. Subsequently, the vulnerability indicator is formed into a composite index. By using fuzzy logic, where the input is a crisis indicator (EMPI) and a vulnerability indicator (composite index), an output i.e., the vulnerability index will be produced. Based on the vulnerability index, the vulnerability level assessment consists of normal, alert, standby, and crisis suspected conditions. Vulnerability assessment results can be taken into consideration in determining the policy responses.

The data used in this research are secondary data from various sources, such as: International Financial Statistics, Statistik Ekonomi dan Keuangan Indonesia, Bank Indonesia, and others. The data used is monthly data of 2002–2012.

3.1. Currency Crisis Indicator

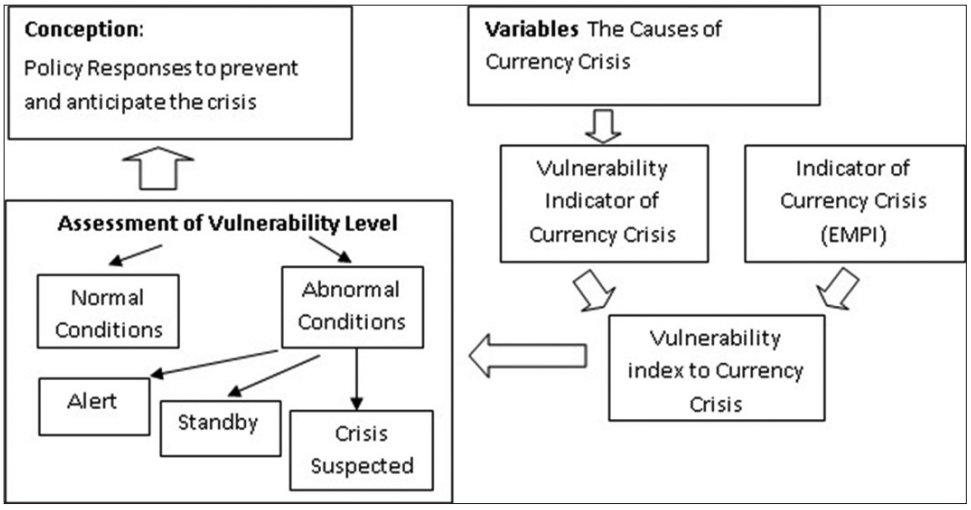
The calculation of exchange market index in this study uses a model of the Index of Currency Market Turbulence from Kaminsky

Figure 1: Block diagram for a fuzzy inference system



Source: Jang et al. (1997)

Figure 2: Conceptual framework



Source: Results from the Concept of Researchers

and Carmen (1999). In this research, the term of EMPI used is shown as follows:

$$EMPI=\frac{\Delta e}{e}-\frac{\sigma_e}{\sigma_R}\cdot\frac{\Delta_R}{R} \quad (1)$$

This index is the weighted average of the rate of change of the exchange rate (Δe/e) and reserves (ΔR/R), Where:
σ_e is the standard deviation of the rate of change of the exchange rate.
σ_R is the standard deviation of the rate of change of reserves.

3.2. Currency Crisis Vulnerability Indicator

The vulnerability indicator of currency crisis is derived from factors that cause the currency crisis having a significant influence in predicting currency crisis. The logistic regression can be used to find the probability of either a crisis or not, where the dependent variable is discrete and qualitative.

Gujarati (2003) provides an equation for the logit model as stated below:

$$P_i=E\left(Y=1|X_i\right)=\frac{1}{1+e^{-(\beta_1+\beta_2 Xij)}} \quad (2)$$

The above equation can be simplified and known as a cumulative logistics distribution function.

$$P_i=\frac{1}{1+e^{-Zi}}=\frac{e^{Zi}}{1+e^{Zi}} \quad (3)$$

With $Z_i=\beta_1+\beta_2 X_i$; for i=1, 2,… n

If we take the natural log of the equation, then we will get the following result:

$$L_i=\ln\left(\frac{P_i}{1-P_i}\right)=Z_i=\beta_1+\beta_2 X_i \quad (4)$$

Li is log of odds which is linear in X and linear in parameters. Li is called a logit, so the above equation is called a logit model.

Logistic regression equation for currency crisis:

$$L_i=\beta_1+\beta_2 BIRATE+\beta_3 CA+\beta_4 CREDIT+\beta_5 ED+\beta_6 ER+\beta_7 EXPORT+\beta_8 GDP+\beta_9 IMPORT+\beta_{10} INFLATION+\beta_{11} M2+\beta_{12} R+\beta_{13} RER+\beta_{14} TOT+\epsilon \quad (5)$$

Independent variables are the factors that cause currency crisis. While the dependent variable is the EMPI which is converted into binary variable form, its value must be a value of 1 and 0, as shown below:

$$EMPI=\begin{cases}1 & \text{if EMPI} \geq \text{mean+1 standard deviation, is crisis}\\ 0 & \text{if EMPI<mean+1 standard deviation, is non-crisis}\end{cases} \quad (6)$$

The vulnerability indicator is formed into a composite index to be used as input in the fuzzy logic process. The first stage is to form a variable index into a single index using min-max method from OECD (2008), Handbook on constructing composite indicators, methodology and user guide.

$$I_i=\frac{X_i-\min X_i}{\max X_i-\min X_i} \quad (7)$$

Where:
I_i is index of variable i
X_i is variable i
min X_i is minimum value of variable i
max X_i is maximum value of variable i

The second stage is to form a composite index of vulnerability indicator consisting of n variables:

$$\text{Composit index}=\frac{1}{n}\sum_{i=1}^{n} I_i \quad (8)$$

3.3. Fuzzy Logic and Vulnerability Index

Fuzzy logic is utilized in order to obtain index of exchange rate vulnerability. These following steps show how fuzzy logic works:

1. Fuzzyfication (the formation of fuzzy set); the process of changing the input system that has a crisp value into linguistic variables.
2. Inference engine (the formation of fuzzy knowledge base); the process of converting the fuzzy input into fuzzy output by following the rules (IF-THEN rules) that have been established on the fuzzy knowledge base, if the system consists of several rules, the inference is obtained from their set and correlation.
3. Defuzzyfication (affirmation); where the input of the defuzzification process is a fuzzy set obtained from the composition of fuzzy rules, while the resulting output is the domain of the fuzzy set. This defuzzyfication uses the centroid method.

Fuzzy logic process starts from FIS. FIS begins with the determination of input and output. For this research, there are two inputs, namely EMPI and composite index. The output is the vulnerability index. Then, the type or model of FIS is determined. This research uses Mamdani model.

The next stage is to determine the membership function for input and output. Membership function is a curve showing the mapping of data input points into membership values or membership degrees that have intervals between 0 and 1. Membership functions for EMPI and composite index are low, medium, and high. Membership function for vulnerability index are normal, alert, standby, and crisis suspected (Table 1).

Determination of fuzzy rules (IF–THEN rules):

An example of a simple fuzzy logic rule can be expressed as follows:

- IF EMPI are medium AND composit index are low.
- THEN vulnerability index is alert.

The last is the output analysis. FIS evaluation provides vulnerability index as the output. Based on the vulnerability index, the level of vulnerability, that is divided into normal, alert, standby, and crisis suspected conditions, can be assessed. To determine the degree of membership of vulnerability index, an evaluation of the membership function can be performed. The result is a degree of membership of the intersection between the vulnerability index value and the normal, alert, standby, or crisis suspected curve.

4. RESULT AND DISCUSSION

4.1. Currency Crisis Indicators

EMPI is an indicator of the currency crisis. The period of crisis is a period of great pressure occurring above or equal to its threshold. By using different thresholds, there are different numbers of crisis period. This study uses the threshold of $\mu + 1\sigma$ to allow more high-pressure periods. When EMPI is $\geq$ threshold $\mu + 1\sigma$, there are 14 crisis periods. With other thresholds, when EMPI is $\geq$ threshold $\mu + 1.5\sigma$, there are 7 crisis periods and when EMPI is $\geq$ threshold $\mu + 2\sigma$, there are 3 crisis periods. The threshold value of $\mu + 1\sigma$ is 0.040597, the threshold value of $\mu + 1.5\sigma$ is 0.065735, and the threshold value of $\mu + 2\sigma$ is 0.090872 (Figure 3).

In October 2008, EMPI achieved the highest pressure of 0.261 with an exchange rate position of 11,050 and foreign exchange reserves of 50,580 million. The high pressure was caused by a change from the previous month period, where there was an increase in the exchange rate of 1544 or 14% and a decrease in foreign exchange reserves of 6528 million USD or 13%. The second highest EMPI was 0.125 with an exchange rate of 12,360 and foreign exchange reserves of 50,182 million in November 2008. The third highest position of EMPI of 0.110 was with an exchange rate of 8875 and foreign exchange reserves of 114,502 million in September 2011. As the position of the exchange rate in September 2011 was quite good, then it might be suspected that the pressure was not huge, but it turned out that EMPI was quite high due to a quite significant change in foreign exchange reserves that was reduced by 10,136 million. EMPI was able to capture such a big change. The crisis period with the lowest EMPI of 0.044 was in June 2005 with the position of the exchange rate of 9760 and the foreign exchange reserves of 33.865 million.

Based on the results of this study, the October 2008 period was the peak of the currency crisis in Indonesia. This is in line with Indonesia's real conditions in the period of October 2008. This proves that EMPI can picture the currency crisis that occurred. In the period of October 2008 when EMPI was the highest, at the same time, capital market shocks in the United States caused global pressure. Global pressure affected the Indonesian economy, so it was obvious that Indonesia was also under high pressure.

4.2. Currency Crisis Vulnerability Indicators

Various variables can be used as indicators. This research is able to acquire monthly data of 2002–2012 from thirteen variables i.e., BI rate, current account, credit, external debt, exchange rate, export, GDP, import, inflation, M2, reserves, real exchange rate, and terms of trade. By using logistic regression and selecting threshold of $\mu + 1\sigma$, this study finds significant variables i.e., current account, credit, exchange rate, export, M2, real exchange rate, and terms of trade. These seven significant variables are then become vulnerability indicators (Tables 2 and 3).

Prediction evaluation is conducted to determine the ability of the model to predict the occurrence of the crisis. The prediction evaluation shows the level of prediction accuracy. For the currency crisis, prediction evaluation shows that the model can predict all non-crisis periods of 118 periods correctly at 100%, and of the 14 crisis periods, only 9 periods were predicted correctly at 64.29%, while 5 periods were predicted to be false by 35.71%. Overall, the model can give correct prediction at 96.21%, obtained from (118 + 9)/132.

4.3. Currency Crisis Vulnerability Index

The level of vulnerability is obtained by exploring the ability of fuzzy logic in linguistic reasoning process and classifying a condition. By using evaluation of FIS, the value of vulnerability index at every period will be identified. In the period of

Table 1: Fuzzy rules

Composite index	EMPI		
	Low	Medium	High
Low	Normal	Alert	Standby
Medium	Alert	Standby	Crisis suspected
High	Standby	Crisis suspected	Crisis suspected

Source: Results of the researcher's design. EMPI: Exchange market pressure index

Table 2: Results of logistic regression

Variable	Threshold μ+1σ	
	Coef.	Prob.
C	−145.6012	0.0059
BI rate	−0.1059	0.8679
Current account	*−2.4543	0.0802
Credit	**0.0001	0.0266
External debt	0.0002	0.1503
Exchange rate	***0.0102	0.0015
Export	**0.0025	0.0244
GDP	0.0000	0.7694
Import	−0.0016	0.1278
Inflation	−0.5309	0.1076
M2	***−0.0001	0.0071
Reserves	0.0000	0.6760
Real exchange rate	***0.8915	0.0059
Term of trade	*−0.3941	0.0831
McFadden R^2	0.5045	
Prob. Chi-square	0.4065	
Observation amount	132	

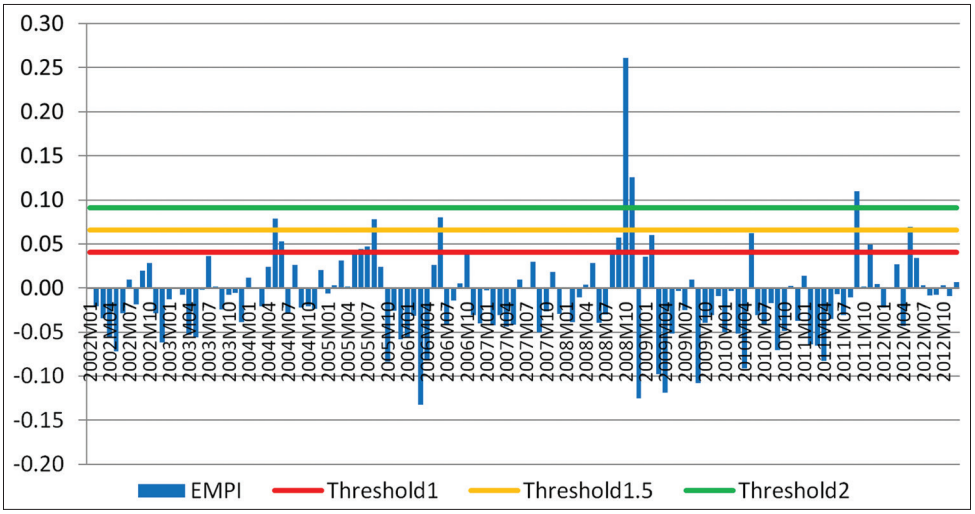
***1% significance level, **5% significance level, and *10% significance level.
Source: Eviews 6 result, processed data. GDP: Gross domestic product

Table 3: Prediction evaluation

	Threshold μ+1σ		
	Estimated equation		
	Dep=0	Dep=1	Total
P (Dep=1)<=C	118	5	123
P (Dep=1)>C	0	9	9
Total	118	14	132
Correct	118	9	127
% Correct	100	64.29	96.21

Source: Eviews 6 result, processed data

Figure 3: Exchange market pressure index January 2002–December 2012



October 2008, the highest EMPI was 0.26097, the composite index of 0.55221, and the vulnerability index value was 0.81061. This value is the largest value of the vulnerability index (Figures 4-6).

The FIS process of currency crisis period in October 2008 is presented as follows:

Input:
1. EMPI (low, medium, high)=0.26097
2. Composite index (low, medium, high)=0.55221.

Output: Vulnerability index (normal, alert, standby, crisis suspected)=0.81061.

EMPI of 0.26097 intersects the low curve at the degree of membership of 2.4958×10^{-5}, intersects the medium curve at the degree of membership of 0.0798, and intersects the high curve at the degree of membership of 0.9944. The composite index of 0.55221 intersects the low, medium, and high curves respectively at the degree of membership of 0.0043, 0.6383, and 0.3714. While the vulnerability index 0.81061 intersects the normal curve, alert, standby, and crisis suspected respectively at the degree of membership of 7.6514×10^{-7}, 0.0034, 0.5966, and 0.4088.

4.4. Vulnerability Level Assessment

This research builds vulnerability index that can provide information on vulnerability levels. The vulnerability index serves as EWS with a vulnerability level classified under normal, alert, standby, and crisis suspected conditions. For vulnerability level assessment, if the index value indicates an alert position, then this index will serve as a warning of the conditions that must be on alert. Thus the information obtained can be used to diagnose the condition and look at what action needs to be taken to anticipate and prevent a crisis.

Based on the data in Table 4, it can be explained that the assessment of vulnerability to vulnerability index 0.81061 is in standby position with degree of membership of 0.5966 which is greater than the degree of membership of crisis suspected position of 0.4088. So in the period of October 2008, the level of vulnerability is more dominant in the standby position. Although the pressure in October

Figure 4: Fuzzy membership function of exchange market pressure index

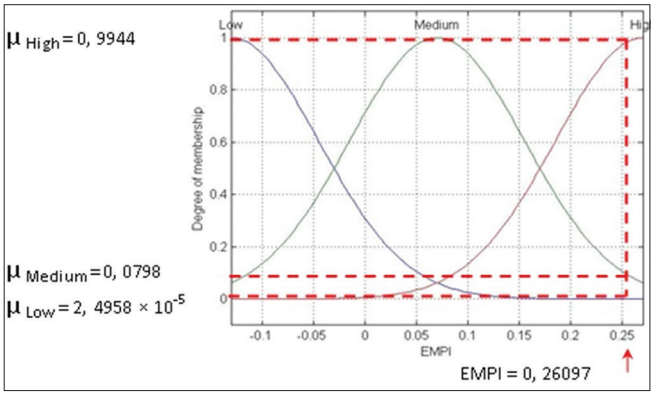
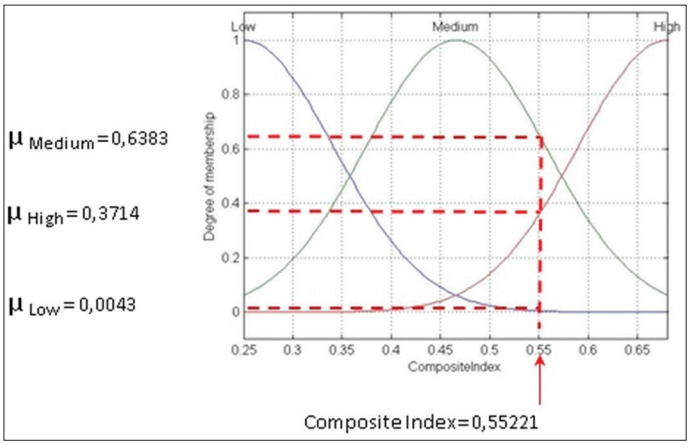


Figure 5: Fuzzy membership function of composite index



2008 on the exchange rate market was very big, the vulnerability indicator was not that big, this is what causes the assessment of the vulnerability condition is still in a standby position, close to the crisis suspected position.

4.5. Early Detection of Vulnerability and EWS

This study does not predict the crisis which occurs for a certain period of time or the duration ahead of the crisis. Instead, it

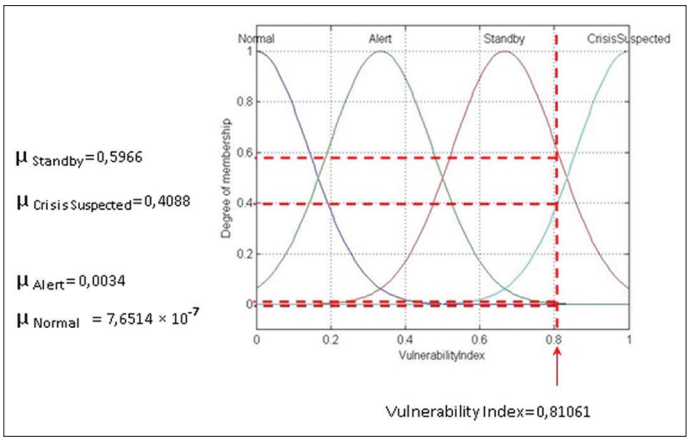
Table 4: Vulnerability level assessment for currency crisis

Crisis period	EMPI	Composite index	Vulnerability index	Evaluation of membership function	
May 2004	0.07888	0.34729	0.48223	0.5752	0.4280
June 2004	0.05251	0.35860	0.50059	0.4976	0.5025
June 2005	0.04406	0.34743	0.48024	0.5837	0.3202
July 2005	0.04679	0.33427	0.45862	0.6759	0.3397
August 2005	0.07800	0.34302	0.47485	0.6067	0.3994
June 2006	0.08015	0.41933	0.59510	0.1810	0.8800
September 2008	0.05700	0.50100	0.62990	0.1115	0.9668
October 2008	0.26097	0.55221	0.81061	0.5966	0.4088
November 2008	0.12534	0.54096	0.67578	0.9979	0.0727
February 2009	0.06013	0.52165	0.63658	0.1009	0.9776
May 2010	0.06215	0.58808	0.68057	0.9952	0.0785
September 2011	0.11007	0.65219	0.79821	0.6497	0.3623
November 2011	0.04939	0.61458	0.69276	0.9832	0.095
May 2012	0.06919	0.53793	0.64983	0.0822	0.9929

Normal
Alert
Standby
Crisis suspected

EMPI: Exchange market pressure index

Figure 6: Fuzzy membership function of vulnerability index



emphasizes the need of information on the extent of vulnerability experienced to serve as an early warning for the crisis. In the meantime, vulnerability index will answer the question of how long the prediction power will occur. It is emphasized from the beginning that the function of EWS in this study is not to predict the crisis period, but to detect vulnerability to crisis. Although this study still uses prediction techniques, the goal is still to measure the ability of the prediction of the model used through logistic regression. The result is a vulnerability index that serves as an EWS that can be used for anticipatory action, which is then followed by control measures.

Basically the vulnerability index is employed to determine the degree of vulnerability, but in connection with the EWS, vulnerability index can serve as an early warning and also the controller. As the vulnerability index increases, it becomes a clear warning that vulnerability to crises is increasing. To avoid the increasing index of vulnerability, controlling the crisis indicator (EMPI) and the vulnerability indicator through its forming variables can be done. While the control function depends on the level of vulnerability targeted.

4.6. The Policy Responses

The policy responses can be made if the information received is complete and comprehensive. According to the IMF (2010), although the crisis is still at an acute stage, the policymakers feel it is urgent to increase their ability to find risks and vulnerabilities that can lead to systemic shocks in order to help them coordinate the initial policy responses.

The information that can be provided for policy responses is a result of vulnerability level assessment. If the appraisal indicates a standby status, it means that a warning of the status of vulnerability must be idle. Further policy responses can be taken depending on the policymakers, whether to reduce the vulnerability status or simply keep the vulnerability status in such level.

To foresee the possibilities that may occur or to identify vulnerability indices for the next few months, 1 year or 2 years, EMPI predictive values and vulnerability indicators can be used in order to assess vulnerability level. Actual data can be used to assess the current condition which would be followed up to evaluate the level of vulnerability. That value of vulnerability index can be used as basis to weigh whether anticipation or control action is needed.

5. CONCLUSION

The analysis of monthly data from 2002 to 2012 indicates that the factors causing a significant currency crisis in predicting the crisis are as follows: Current account, credit, exchange rate, export, M2, real exchange rate, and terms of trade. Those are indicators of vulnerability to currency crisis. Therefore, the change of vulnerability indicators must be monitored continuously to detect Indonesia's vulnerability to currency and banking crisis early.

To measure the level of vulnerability to currency and banking crisis, fuzzy logic is used to produce vulnerability index. This vulnerability index is designed by involving the knowledge and understanding of researchers through the establishment of the

fuzzy membership and the IF-THEN rules. The inputs are EMPI and vulnerability indicators while the output is the vulnerability index. The result of the vulnerability index will reflect the degree of vulnerability that can be used to monitor economic conditions. The vulnerability index will be used in determining the assessment of the economic condition whether it is in normal, alert, standby, or crisis suspected. The result of vulnerability assessment can be used as the basis of consideration for the policy responses to anticipate and prevent the crisis. Appropriate policy responses can be taken after obtaining result on assessment of vulnerability conditions. Policy responses can include anticipatory, preventive, or control measures depending on the assessment of the vulnerability level and the target to be achieved.

The suggestion for further research is to conduct research on vulnerability to crises by using other methods as a comparison. Another suggestion is to conduct research that can improve or refine this research to produce a better model.

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