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Macroeconomic Indicators as A Signal of The Currency Crisis in The Indonesian Economy

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ABSTRACT

This study aims to determine the best model for a currency crisis in Indonesia (1991-2019) influenced by Fundamental and Contagion Effects. Fundamental factors consist of many macroeconomic indicators, while contagion is the impact of the crisis in other countries (Philippines, Korea, Thailand, Malaysia). The determination of a crisis period is based on the critical value of the EMPI (Exchange Market Pressure Index); the signal analysis approach ascertains the signal source of the vulnerability of macroeconomic indicators. The Fundamental and Contagion Effects in EMPI are modeled as the Polynomial Distributed-Lag. Apart from being better than cross-section data modeling, this model was also used to determine when the initial shock crisis happened. It complements Minsky's approach, which analyzed the crisis from the initial causes. Modeling using macroeconomic indicators shows that Fundamental and Contagion Effects are crucial in EMPI. Conversely, modeling only involving Leading Indicators shows that Contagion Effects are insignificant in EMPI. This means that Leading Indicators dominantly determine EMPI behavior, denying the role Contagion Effect.

JEL Classification: G20, G29

Keywords: Contagion Effect; Distributed-Lag Polynomial Model; Exchange Market Pressure Index; Fundamental; Signal Analysis

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INTRODUCTION

Currency crises are strongly influenced by macroeconomic conditions (Dooley, 1999); Corsetti et al., 1998). Macroeconomic variables have different degrees of vulnerability as an indicator of a currency crisis. A group of macroeconomic indicators highly vulnerable to crises is commonly known as the Leading Indicator. Since several studies have selected many macroeconomic indicators, the Leading Indicator aggregates the four most vulnerable macroeconomic indicators. These studies include Krugman (1979), Ozkan and Sutherland (1995), Adiningsih et al. (2002), Herrera and Garcia (1999), and Tinakorn (2002). However, other studies determined leading indicators, including Tambunan (2003), with nine indicators.

Currency crises are the sharp depreciation of a country's currency due to speculative attacks. The crises are usually followed by the depletion of foreign exchange reserves due to the sale of foreign currencies and increased interest rates to maintain exchange rate stability. (Glick and Hutchison, 2011). In general, currency crises are identified with the Exchange Market Pressure Index (EMPI), originally developed by Girton and Roper (1977). This formula consists of the average exchange rate and a decline indicator for the country's international reserve. The EMPI can describe the successful attack on a country's currency indicated by a steady depreciation, and the unsuccessful attack determined by a decrease in foreign exchange reserves or an increase in domestic interest rates (Kaminsky et al. 1988; Goldstein et al., 2000). There are various research objectives for currency crises. Therefore different approaches and models were used by researchers, namely Hernandez (2001), Liu (2009), Kaminsky et al. (1998), Frankel and Rose (1996), Kumah (2007), and Kyin et al. (2013).

Efforts to anticipate currency crises systemically have created a monitoring instrument known as the Early Warning System. The instrument allows predicting the emergence of crises within a well-defined period. (Antoaneta and Gurau, 2019). Research related to the Early Warning System (EWS) was developed by different analysts, namely Krugman (1979), Ozkan and Sutherland (1995), Goldfajn and Faldes (1997), Hardy and Pazarbasioglu (1998), Kaminsky et al. (1995), Several EWS approaches were applied to Indonesia's economy, which includes the Tjahjono (1998), that examined the causes of Asia's crises. This approach also makes use of two factors: the Fundamental and Contagion Effects, developed by Kaminsky and Reinhart, which proves that an attack on one country's currency has a significant impact on their market participants: as a result, it affects other nations' currency having a trading partnership with them, or it can be stated that the Contagion Effect plays an important role in triggering the financial crisis in Asia.

One of the EWS approaches, the Signal Approach Study, was developed by Goldstein et al. (2000) specifically for emerging market countries. The study covered 25 countries with 29 banking crises and 89 exchange rate crises. The approach produces relatively accurate estimates to detect exchange rate and banking crises in various countries, including the Philippines, Korea, Thailand, Malaysia. Despite experiencing the exchange rate crisis, the existing indicators in Indonesia have relatively low probability signals, with the rank of 25 (January 1996 - June 1997) and 23 (January 1996 - December 1997) grouped into the least vulnerable category.

Sometimes indicators give false alarm signals in crisis detection, such as crises occurring in windows periods. There are difficulties in determining indicators because a high probability of predicting a crisis is often accompanied by high noise. Therefore, the main indicators are usually determined using low disturbances and high weight.

Indonesia’s case is interesting to study because one of the indicators with a relatively small probability (below the threshold) is the real exchange rate, which may have contributed greatly to the currency crisis. The question is why the real exchange rate, the leading indicator contributing significantly to the crisis, does not show signals during windows periods. In the other countries in the same region experiencing a crisis, the real exchange rate always created a crisis signal. Due to estimation problems, Goldstein et al. (2000) could not place the real exchange rate as the leading indicator of the crisis. Therefore, this research uses Hodrick-Prescott (H.P.) Filter (Hodrick, 1997) to estimate data trends and deviations to produce the exchange rate as a leading indicator of the crisis. Adjustment of trend sensitivity for short-term fluctuations is achieved by modifying the λ multiplier of equation $y_t = \tau_t + e_t + \epsilon_t$, where y_t for t=1,2, 3,..., and T denotes the logarithm of the time series variable. The y_t series consists of a *trend* τ_t, seasonal e_t, and an error ϵ_t, components. The larger the value of λ, the more penalties, meaning that fewer signals are detected. Contrastingly, the smaller the value of λ, the fewer the penalties, meaning that more signals are detected.

Research to determine the contributions of Fundamental and Contagion Effects to the currency crisis was modeled differently in cross-sections by Sussangkarn and Tinakorn (2003), Adiningsih et al. (2002), and Yap (2003). These studies examined how much each variable contributes to the currency crisis simultaneously. The cross-sectional study simultaneously measures observations and the influence of macroeconomic indicators of fundamentals and contagion effects on the currency crisis. However, this model cannot identify early when the initial shock starts, resulting in a crisis.

According to Minsky's (1992) approach, it is important to map the early indications by identifying the initial shock, the main cause of the initial currency crisis. Conversely, the initial shock can be seen when the macroeconomic indicators began to have a significant effect resulting in a crisis. Therefore, a cross-section approach alone cannot answer this problem.

This study recognizes the time lag and how much the currency crisis is influenced by each macroeconomic indicator for the anticipation to be conducted early. The distributed-lag approach was used to identify this problem (Almon, 1965). This approach shows how far these macroeconomic indicators have influenced the currency crisis. Similar approaches were used by Pradana et al. (2016), Majid et al. (2018), Basistha and Teimouri (2015). The Polynomial Distributed Lag (PDL) approach detects the initial shock of the currency crisis. It complements Minsky's (1992) approach, which analyzed the crisis from the initial causes. In case the Minsky approach focuses on initial factors causing the crisis, the PDL approach will examine since when the crisis began, an aspect that has not been examined in the previous research.

The approach used by Adiningsih et al. (2002) in determining the Leading Indicator was developed by Herrera and Garcia (1999), involving updating leading indicators at a certain time. This approach is more efficient, quick, and requires fewer data about the many macroeconomic indicators. However, economic indicators do not always become leading indicators because the initial shock varies with crises (Minsky, 1992). Therefore, this study uses the Kaminsky approach to determine leading indicators to improve accuracy, though it requires relatively more data.

REVIEW OF LITERATURE

Relationship between Fundamental and Contagion effect as well as Currency Crisis

There are at least three underlying theories for the currency crisis, including the crisis of the first, second and third generations. According to the first generation, the crisis is caused by weak macroeconomic fundamentals. The second-generation theory occurs because of the role of economic actors' expectations as the crisis source. This happens even in the absence of fundamental weaknesses, such as the perception of an overvalued domestic currency, encourage economic actors to change their portfolios into a currency safe from speculation attacks. The third-generation theory sees the currency crisis as a financial panic caused by the ineffective banking intermediary when money and credit increase (Claessens, 2005).

The first generation crisis model was caused by inconsistent macroeconomic policies. The authorities wanted to maintain a fixed exchange rate regime while increasing domestic credit to achieve economic goals. The increase in domestic credit could cause a devaluation, promoting speculative attacks as initial shocks to the currency crisis. This model is supported by Sachs et al. (1996), Ford et al. (2007), Feridun (2009), Agenor et al. (1992), Lahiri and Veg (2003).

The model formulation is consistent with the conditions in Sarno and Taylor (2002), where, initially, the exchange rate, price, and interest rate did not change. However, the fiscal policy implemented by the government needed financing through government debt, increasing money offer. The domestic price increases to maintain its parity with foreign interest rates. This depreciated the domestic currency relative to foreign currencies. Therefore, the authorities bought domestic currency to maintain the exchange rate at a certain level, reducing international reserves.

The intervention is successful when the reduction in international reserves equals the increase in domestic credit, maintaining equilibrium in the money market. However, it depletes international reserves and inhibits authorities from maintaining a fixed exchange rate regime, enabling speculators to attack the domestic currency.

According to the first generation of currency crises, speculative attacks depend on actual fundamentals and expectations and a wide variety of speculators' expectations. Furthermore, it depends on the expected good and bad fundamentals, which affect the exchange rate pressure index (Prati and Sbaracia, 2002).

Speculative attacks could succeed in the second-generation crisis model, despite monetary and fiscal policies being consistent with the fixed exchange rate system. However, the authorities performed devaluation and implemented expansion monetary policy to improve the trade balance. The slight changes in monetary and fiscal policies altered the exchange rate system due to speculative attacks on the domestic currency.

The third generation crisis model involves a banking crisis through moral hazards (Mckinnon and Pill, 1998). Guarantees for domestic financial institutions make capital inflows to obtain returns and reduce risks. This supports the banking sector to conduct excessive and overvalued lending, resulting in bad loans (Goldstein et al., 2000). The bad loans reduced asset values, causing market panic exacerbated by speculative attacks. This resulted in capital outflows, eroded foreign exchange reserves, and heavy depreciation pressures.

The third-generation crisis is also due to the illiquidity model as the potential for bank runs when facing liquidity risk (Chui, 2002). The inability of a bank to meet customer cash demands causes massive withdrawals by customers and affects other banks (self-fulfilling) (Chang and Velasco, 2001).

Moral hazard and illiquidity models have components of the first-and second-generation crisis models (Chui, 2002). This combination is called a cross-generation model, the basis for various structural model studies, such as Kumah (2007) and Cerra and Saxena (2005). The explanatory variables of the third-generation crisis include capital account liberalization, Growth in M2 multiplier, Growth in credit or GDP, and the Ratio of domestic bank loans to GDP. Other variables are the Liabilities to GDP ratio, Fall in bank deposits to GDP ratio, Contagion dummy, and Short-term capital flows or GDP (Radelet and Sachs, 1998). Therefore, contagion is a manifestation of the third-generation crisis.

Eichengreen et al. (1996) showed that a crisis in one country increases the probability of a crisis in another country due to the contagion effect. This could be explained more by trade linkages than the fundamental macroeconomic similarities.

Macroeconomic fundamentals cannot explain exchange rate pressures in the short term but rather informational effects (Chu et al., 2000). For example, a fall in a country's currency exchange rate provides information for economic actors to reassess the stability of another country's currency. The contagion that occurs when based on cluster analysis shows that the currency crisis will spread to countries in the region with similar macroeconomic fundamentals (Chu et al., 2000).

Supporting research, such as Tjahjono (1998) using the Kaminsky et al. (1998) approach, classifies emerging market countries in Asia with relatively similar macroeconomic fundamentals. These include countries affected by the crisis, such as Thailand, Indonesia, Malaysia, Korea, and the Philippines. The countries not affected by the crisis included Singapore, Hong Kong, Taiwan, and Japan. This study chooses Thailand, Malaysia, Korea, and the Philippines as the contagion effect for Indonesia.

Early Warning System Models

Kaminsky et al. (1998) carried out early detection of currency crises using a signal approach by identifying the vulnerability level of macroeconomic indicators that affected currency crises. Specifically, the currency crisis was measured in terms of the exchange market pressure index (EMPI). Hegerty (2013) used a signal approach to determine the interrelationships of the contagion effect on the currency of each country against others in Africa, based on the EMPI. Buyukakin and Aydin (2018) developed the KLR Signal Approach in Turkey, finding a new crisis variable. Megersa and Cassimon (2013) used the same approach and successfully identified three currency crisis episodes during 1970-2008, each with a different dynamic.

The Developing Country Studies Division (DCSD) model was developed from the KLR model using the same crisis definition and prediction horizon. Multivariate probit regression was performed, assuming that the crisis probability would increase linearly with changes in the predictive variables (Koo et al., 2005). The variables generated from this model include overvaluation, current account, the decline in foreign exchange reserves, export growth, and the ratio of debt to foreign exchange reserves.

The Early Warning System (EWS) developed by the IMF is the Policy Development and Review (PDR) model. It involves adding balance sheet variables and standard proxies to the DCSD model (Mulder et al., 2002). Corporate sector data is available annually with a significant lag. Although these variables move slowly, they contribute to accurate forecasting.

Currency Crisis Study

Empirical studies on currency crises could essentially be grouped into several categories. Kruger et al. (1998) categorized empirical models based on currency crisis into structural and non-structural models. Furthermore, Esquivel and Larrain (1998) divided the causes of currency crises into two groups. The first group focuses on one country during the crisis, while the second focuses on analyzing countries using cross-section or panel data. Also, Kaminsky et al. (1998) selected 25 empirical studies on currency crisis models by classifying them into four categories.

Berg and Pattillo (1998) tested three different econometric models to predict the 1997 currency crisis using Kaminsky et al. (1998), Frankel and Rose (1996) and Sachs et al. (1996) models. The results showed that none of the models could predict the currency crisis in 1997. However, the KLR approach by Kaminsky et al. (1998) showed the suitable indicators that significantly predict the probability of the 1997 crisis. Therefore, the KLR approach could identify the countries prone to crisis, making it better than the other models. However, the three approaches showed that a country's economic fundamentals influence the currency crisis probability. These include the high domestic credit, overvalued real exchange rate relative to the trend, and the high ratio of M2 to international foreign exchange reserves. Poor fundamentals increase the crises occurrence probability, though the timing cannot be accurately predicted. Speculators observe that poor fundamentals make a currency vulnerable to attack. However, the timing of the attack is determined by the fundamentals' probability of profiting by attacking the currency, resulting in the term multiple equilibria.

RESEARCH METHODOLOGY

Identification of Currency Crisis

In general, the features of the currency crisis include exchange rate depreciation due to the decrease in foreign exchange reserves and the increase in the interest rates. The approach commonly used is Exchange Market Pressure Index (EMPI) by Griton and Roper (1977), which continues to experience development by Weymark (1998), with the following model:

$$EMP_t = \Delta e_t + \varphi \Delta r_t \tag{1}$$

where Δe_t is the nominal change in the exchange rate, Δr_t is the change in the central bank's foreign exchange, φ= -$\frac{\partial \Delta e_t}{\partial \Delta r_t}$ is elasticity.

Eichengreen (1995) emphasizes the response of monetary policy during the crisis and incorporates the interest rate policy into the EMPI calculation, therefore:

$$EMP_t = \Delta e_t + w_r \Delta r_t + w_i \Delta i_t \tag{2}$$

where w_r is the ratio of changes in foreign exchange in EMPI, w_i is the change ratio in interest rates of EMPI. The calculations performed by Eichengreen et al. (1996) defined the EMPI as:

$$EMPI_{i,t} = \frac{1}{\sigma_\varepsilon}\frac{\Delta e_{i,t}}{e_{i,t}} - \frac{1}{\sigma_r}\left(\frac{\Delta rm_{i,t}}{rm_{i,t}} - \frac{\Delta rm_{us,t}}{rm_{us,t}}\right) + \frac{1}{\sigma_i}\Delta\left(i_{i,t} - i_{us,t}\right) \tag{3}$$

where $EMPI_{i,t}$ is the EMPI of country i in period t, $e_{i,t}$ is the exchange rate of country i's currency against the U.S. dollar, σ_e is the standard deviation of the relative changes in the exchange rate $\frac{\Delta e_{i,t}}{e_{i,t}}$; $rm_{i,t}$ is the ratio of gross foreign reserves to the money stock or monetary base of country i in period t; σ_r is the standard deviation of the difference between the relative changes in foreign reserves and money in country i and the reference country (U.S.) $\left(\frac{\Delta rm_{i,t}}{rm_{i,t}} - \frac{\Delta rm_{us,t}}{rm_{us,t}}\right)$ in period t; $i_{i,t}$ is the nominal interest rate in country i in period t; $i_{us,t}$ is the nominal interest rate in the reference country (U.S.) in period t, and σ_i is the standard deviation of the nominal interest rate differential $\Delta(i_{i,t} - i_{us,t})$.

Subsequent studies such as Sachs et al. (1996) define EMPI as follows:

$$EMPI_{i,t} = \left(\frac{\frac{1}{\sigma_e}}{\left(\left(\frac{1}{\sigma_e}\right)+\left(\frac{1}{\sigma_r}\right)+\left(\frac{1}{\sigma_i}\right)\right)}\right)\frac{\Delta e_{i,t}}{e_{i,t}} - \left(\frac{\frac{1}{\sigma_r}}{\left(\left(\frac{1}{\sigma_e}\right)+\left(\frac{1}{\sigma_r}\right)+\left(\frac{1}{\sigma_i}\right)\right)}\right)\frac{\Delta r_{i,t}}{r_{i,t}} + \left(\frac{\frac{1}{\sigma_i}}{\left(\left(\frac{1}{\sigma_e}\right)+\left(\frac{1}{\sigma_r}\right)+\left(\frac{1}{\sigma_i}\right)\right)}\right)\Delta i_{i,t} \quad (4)$$

where $EMPI_{i,t}$ is the Exchange Market Pressure Index for country i in period t; $e_{i,t}$ is the exchange rate of country i's currency against U.S. Dollar in period t; $i_{i,t}$ is the nominal interest rate of country i in period t; σ_e is the standard deviation of the change in exchange rates ($\frac{\Delta e_{i,t}}{e_{i,t}}$); σ_r is the standard deviation of the change in foreign reserves ($\frac{\Delta r_{i,t}}{r_{i,t}}$); and σ_i is the standard deviation of the change in the nominal interest rate $\Delta i_{i,t}$.

The method used in this study is as conducted by Kaminsky et al. (1998,1999), which defines EMPI as follows:

$$EMPI_{i,t} = \frac{\Delta e_{i,t}}{e_{i,t}} - \frac{\sigma_e}{\sigma_r}\frac{\Delta r_{i,t}}{r_{i,t}} + \frac{\sigma_e}{\sigma_i}\Delta i_{i,t} \quad (5)$$

where $EMPI_{i,t}$ is the Exchange Rate Market Pressure Index for i-country in t-period; $e_{i,t}$ is the exchange rate of the i-country's currency against the U.S. dollar in t-period; $r_{i,t}$ is the gross foreign reserves of i-country in t-period; $i_{i,t}$ is the nominal interest rate of i-country in t-period; σ_e is the standard deviation of the rate of change in the exchange rate ($\frac{\Delta e_{i,t}}{e_{i,t}}$), σ_r is the standard deviation of the change rate in foreign reserves ($\frac{\Delta r_{i,t}}{r_{i,t}}$); σ_i is the standard deviation of changes in the nominal interest rates $\Delta i_{i,t}$.

According to Kaminsky et al. (1998, 1999), the use of the EMPI definition was based on Goldstein et al. (2000), which used a similar definition of EMPI to determine whether using the Hodrick-Prescott (H.P.) Filter to estimate trends and deviations in the real exchange rate can place the real exchange rate as the leading indicator of the crisis. However, Goldstein et al. (2000) did not produce the leading indicators of the crisis because of the low signal (below the threshold). This is consistent with Berg and Pattillo (1998), which stated that the model is better than the other two (Frankel and Rose, 1996 and Sachs et al., 1996).

The identification of currency crises using the Three-sigma rule is based on the mean of the sample plus the standard deviation δ (Knedlik, 2006), with the critical value of EMPI as follows:

$$Crisis = \left(\frac{1, if EMP_{i,t} > \mu_{EMP} + \delta.\sigma_{EMP}}{0, otherwise}\right) \quad (6)$$

where: μ_{EMP} is the mean value of the EMPI sample, σ_{EMP} is the standard deviation of the EMPI sample.

A similar approach was used by Bertoli et al. (2006), where crisis threshold was determined in a discretionary manner and compared with standardized EMPI.

$$IC_t = 1 \; if \; \frac{EMPI_t - \mu_{EMPI}}{\sigma_{EMPI}} > \tau$$
$$IC_t = 0 \; if \; \frac{EMPI_t - \mu_{EMPI}}{\sigma_{EMPI}} \leq \tau \quad (7)$$

There is no standard in determining the critical value, but it constantly ranges from 1 to 3, like Eichengreen et al. (1996); Aziz et al. (2000), Bordo et al. (2001) use critical value: 1.500, Caramazza et al. (2000): 1.645, Kamin et al. (2001): 1.700, Eichengreen et al. (1994), Glick and Huchinson (2001): 2.000, Edison (2003): 2.500 dan Kamisnky and Reinhart (1999), Berg and Patillo (1999): 3.000. Therefore, the smaller the critical value, the fewer the filtered out signals. Thus more signals emerged, but most were false. This study uses a critical value = 1.500, as conducted by Eichengreen et al.(1996), Aziz et al. (2000), and Bordo (2001). Therefore, the signal that comes out is not too much filtered and has relatively good accuracy.

Macroeconomic Indicators

Macroeconomic indicators were divided into two, Fundamental and Contagion Effects, and the sectoral grouping was conducted by Lestano et al. (2003), which was grouped into six sectors with 25 macroeconomic indicators. Sussangkarn and Tinakorn (2003) divided 23 macroeconomic indicators into five sectors, while Tambunan (2003) used only nine indicators.

In principle, the disadvantage of using more macroeconomic indicators is that it requires a relatively large amount of data that is not always available. Furthermore, the data could be already represented by other indicators. These indicators only contribute relatively little in providing a signal for the formation of the composite index. However, it produces rich information because with the many indicators used, certain sectors that give disturbance signals can be detected, although a crisis may not necessarily occur. Using relatively few indicators make it easier to provide data and operate, though the more detailed economic sectors cannot be absorbed in the event of a disruption.

This study uses indicator determination suggested by Kaminsky et al. (1998) chose the following indicators: 1) Foreign exchange reserves, 2) Exports, 3) Imports, 4) Term of Trade, 5) Real exchange rates, 6) Differences between real domestic interest against foreign, 7) Excess M1 real balance, 8) M2 multiplier, 9) Domestic credit / GDP ratio, 10) Real deposit interest rate, 11) Loan/deposit interest ratio, 12) Bank deposits, 13) Ratio of M2 / Foreign exchange reserves, 14) Output indexes, 15) Stock price indexes (Abhimanyu, 2008).

This study uses the 15 macroeconomic indicators by Kaminsky et al. (1998) as the fundamental basis of the sectoral grouping. In order to avoid seasonal influences, data is modified in the form of year-on-year (Bhattacharya et al. 2016, Dunbar, 2013) and deviated from transformation into the real exchange rates using Hodrick-Prescott (H.P.) filter (Hodrick, 1997).

Signal Analysis Approach

Several alternatives to determine the period before the crisis (window period) range in months, such as 12 (Mohana and Padhi, 2019), 18 (Knedlik and Scheufele, 2007), 24 (Kaminsky et al., 1997; Glick and Hutchison, 2011), and 36 (Zheng et al., 2012). Determining a window period that is too short deprives policymakers of enough time to anticipate a crisis. Suppose it is too long. There is a tendency for forecasting to look good, even though there could be a probability of a crisis occurring. This Analysis Approach was used for signal generation (Kaminsky et al., 1997) using a 24-month signaling horizon. When the observed indicator is in an abnormal area, it gives a sign of crisis. Therefore, when a crisis is observed in the 24 months, the signal is correct (category A), and when there is none, this indicates false, categorized as B (type II error). When the indicator does not give a sign, then in these periods, there should be no crisis (category D). In case there is a crisis, it is categorized as C (type I error).

Table 1 Indicator Signal Matrix

	Crisis in the signaling horizon.	**No crisis in the signaling horizon.**
Signal	A	B
No Signal	C	D

Sources: Kaminsky, Lizondo, and Reinhart (1997).

Each indicator had a different performance and was measured according to the principle of Goldstein et al. (2000), by classifying unconditional probability of a crisis, denoted by P (Crisis) = (A + C) / (A + B + C + D), and the conditional which was represented by P(Crisis│ S) =A/(A+B). (Phadan and Prabheesh, 2019). The amount of marginal predictive power is P(Crisis│ S)- P (Crisis) and also known as Noise-to-Signal Ratio (NSR):

$$Noise-to-Signal-Ratio = \frac{B/(B+D}{A/(A+C)} \tag{8}$$

The composite index of the indicators was determined with the assumption that the more the number of signals, the higher the composite index, which means the greater the possibility of a crisis. (Tambunan, 2003). The calculation is carried out by counting the individual indicators that passed through the threshold in a particular month, using the equation as follows:

$$I_t^{(1)} = \sum_{j=1}^{n} S_t^j \tag{9}$$

S_t^j= 1 when the *j* variable passed the threshold in the t period, and S_t^j= 0 for the others. The smaller the ratio value, the better the performance of the signal produced. When the indicator of this ratio was equaled to one, it showed a false signal. Since individual indicators had different performance, the composites were based on the weight or magnitude of their NSR, thus:

$$I_t^{(1)} = \sum_{t=1}^{n} S_t^j . \frac{1}{W^j} \tag{10}$$

where: W^j= Noise-to-Signal Ratio of j variable.

The accuracy of composite indicators was measured by the Quadratic Probability Score (QPS). (Berg and Pattillo, 1999). When T forecasted probability was $\{P_t\}_{t=1}^{T}$, P_t was the probability of a crisis [*t*,*t*+*h*] from the signal produced in t period, and $\{R_t\}_{t=1}^{T}$as real-time series, with R_t=1 when a crisis occurred in the range t and *t* + *h*, and R_t=0, when there was no crisis, then the Quadratic Probability Score (QPS) was formulated as follows:

$$QPS = \frac{1}{T}\sum_{t=1}^{T} 2(P_t - R_t)^2 \tag{11}$$

where QPS has a range between 0 to 2, and 0 = perfect accuracy.

The other method was the Log-Probability Score (LPS) with the following equation:

$$LPS = -\frac{1}{T}\sum_{t=1}^{T}[(1-R_t)ln(1-P_t) + R_t ln(P_t)] \tag{12}$$

where LPS has a range of 0 to ∞, with a value of 0 = perfect accuracy (Park, 2003).

The test for accuracies of the forecasted probabilities and relative frequencies were conducted by predicting the calibration using the Global Bias Squares (GBS) as follows:

$$GBS = 2(\bar{P} - \bar{R})^2 \tag{13}$$

where: $\bar{P} = \frac{1}{T}\sum_{t=1}^{T} P_t$, and $\bar{R} = \frac{1}{T}\sum_{t=1}^{T} R_t$.The value of GBS was between 0 and 2, where 0 was the perfect global calibration. This indicated that the average reality value equaled the mean forecasted probability. (Budsayaplakorn et al., 2010).

The resulting accuracy using either QPS or LPS is relatively the same. Therefore, this study uses QPS to determine forecasting accuracy and GBS to see the forecasting calibration.

Data Description

Data were obtained from International Financial Statistics (IFS), SEKI (Indonesian Economic and Financial Statistics), Bank Indonesia, World Bank, and Investing.Com from 1991 (1) -2019 (12).

Variables that need operational explanation include currency crisis variables identified from the Exchange Market Pressure Index (EMPI as in equation (5), where $e_{i,t}$ is obtained from rows 1 (Indonesia), 4 (Korea), 7 (Malaysia), 10 (Philippines) and 13 (Thailand). $r_{i,t}$ is obtained from rows 3 (Indonesia), 6 (Korea), 9 (Malaysia), 12 (Philippines), and 15 (Thailand). Furthermore, i_{it} is obtained from rows 2 (Indonesia), 5 (Korea), 8 (Malaysia), 11 (Philippines), and 14 (Thailand). The real output obtained from Nominal GDP is converted to constant price GDP (constant price GDP for different years should be converted to constant price GDP in the same year, which uses constant price GDP in 2010 in this study) (Mankiw, 2019), as shown in line 28. Excess M1 Real Balance is the residual of real M1 regression with real GDP, inflation, and predetermined trend. (Kaminsky et al., 1998). Real M1 and GDP are obtained from lines 20 and 28, respectively. Inflation is obtained from the growth rate of the Consumer Price Index found in line 22. M2 Multiplier, as a significant change in reserve equity (Kaminsky et al., 1998), is found on line 21. Interest Rate Real Savings is the nominal interest rate minus the inflation rate. (İskenderoğlu, 2011). The nominal interest rate is found in line 2, while the inflation rate is derived from the growth rate of the Consumer Price Index on line 22. The real exchange rate is (nominal exchange rate X domestic CPI) / USA CPI.

Kaminsky et al. (1998) emphasize that it is the result of multiplying row 1 and row 22, divided by row 17. Trade Exchange Rate is the ratio of export to import (Kaminsky et al. 1998), specifically row 23 divided by row 24.

Econometric model

EMPI (= Y) was the sum of three components: the nominal exchange rate, the level of foreign exchange reserves, and the domestic interest rate. The EMPI approach used by Kaminsky et al. (1998, 1999) is like in equation (5), where the method provides greater weight to changes in exchange rates than the difference in foreign exchange reserves and interest rates. Therefore, the percentage change in exchange rates is not weighted for the standard deviation like the other components.

The Fundamental (= X1) was determined based on the composite index resulting from the sum of each macroeconomic indicator, both the fifteen and the leading four, and weighting each based on the NSR (Noise to Signal Ratio). The Contagion effect (= X2) was determined based on the sum of the effects from other countries, and weighting each based on the NSR value, where: 1 = Other countries had crises in t period, 0 = other countries did not experience a crisis. Malaysia, Thailand, the Philippines, South Korea were chosen as the contagion effects because they are in the region with relatively similar macroeconomic fundamentals to Indonesia (Tjahjono, 1998, Kaminsky, 1998).

Based on the assumption that EMPI was not only influenced by the two variables (Fundamental and Contagion effect) at t-time, but also with time-lag, therefore modeling in the form of distributed-lag is as follows:

$$Y_t = \alpha + \sum_{i=0}^{k} \beta_i X_{1(t-i)} + \sum_{j=0}^{k} \beta_j X_{2(t-j)} + u_t \tag{14}$$

where:

Y_t	=	EMPI (Exchange Market Pressure Index) at the t-time,
α	=	A constant,
k	=	The maximum lag size,
β_i	=	The coefficient that describes the contribution of the fundamental economic variables to the EMPI,
β_j	=	The coefficient that describes the contribution of the contagion effect variables to the EMPI,
X_1	=	Economic Fundamental Variable,
X_2	=	Contagion Effect Variable,
u_t	=	Random Error at t-time,
i	=	The magnitude of lag in fundamental economic variables in its contribution to EMPI,
j	=	The magnitude of lag in contagion effect variables in its contribution to EMPI.

Based on Weierstas's Theorem, assuming that β_i and β_j were estimated by polynomials with the appropriate degree of *i* and *j* as lag length (Almon, 1965), thus it was written as follows:

$$\begin{gathered}\beta_i = a_{1(0)} + a_{1(1)}i + a_{1(2)}i^2 + \cdots + a_{1(m)}i^m \text{ and} \\ \beta_j = a_{2(0)} + a_{2(1)}j + a_{2(2)}j^2 + \cdots + a_{2(m)}j^m\end{gathered} \tag{15}$$

which was the m-polynomial degree of *i* and *j*, assuming that *m* (polynomial degree) was smaller than *k* (maximum lag size).

Furthermore, by substituting equation (15) into equation (14), thus:

$$\begin{aligned}Y_t = \alpha + \sum_{i=0}^{k}\left(a_{1(0)} + a_{1(1)}i + a_{1(2)}i^2 + \cdots + a_{1(m)}i^m\right)X_{1(t-i)} \\ + \sum_{j=0}^{k}\left(a_{2(0)} + a_{2(1)}j + a_{2(2)}j^2 + \cdots + a_{2(m)}j^m\right)X_{2(t-j)} + u_t\end{aligned}$$

$$\begin{aligned}Y_t = \alpha + a_{1(0)}\sum_{i=0}^{k} X_{1(t-i)} + a_{1(1)}\sum_{i=0}^{k} iX_{1(t-i)} + a_{1(2)}\sum_{i=0}^{k} i^2X_{1(t-i)} + \cdots + a_{1(m)}\sum_{i=0}^{k} i^mX_{1(t-i)} + a_{2(0)}\sum_{j=0}^{k} X_{2(t-j)} \\ + a_{2(1)}\sum_{j=0}^{k} jX_{2(t-j)} + a_{2(2)}\sum_{j=0}^{k} j^2X_{2(t-j)} + \cdots + a_{2(m)}\sum_{j=0}^{k} j^mX_{2(t-j)} + u_t\end{aligned}$$

If: $Z_{1(0t)} = \sum_{t=0}^{k} X_{1(t-i)}$, $Z_{1(1t)} = \sum_{i=0}^{k} iX_{1(t-i)}$, $Z_{1(2t)} = \sum_{i=0}^{k} i^2X_{1(t-i)}$, $Z_{1(mt)} = \sum_{i=0}^{k} i^mX_{1(t-i)}$, $Z_{2(0t)} = \sum_{t=0}^{k} X_{2(t-j)}$, $Z_{2(1t)} = \sum_{j=0}^{k} jX_{2(t-j)}$, $Z_{2(2t)} = \sum_{j=0}^{k} j^2X_{1(t-j)}$, $Z_{2(mt)} = \sum_{j=0}^{k} j^mX_{1(t-j)}$, then it can be written as follows:

$$\begin{aligned}Y_t = \alpha + a_{1(0)}Z_{1(0t)} + a_{1(1)}Z_{1(1t)} + a_{1(2)}Z_{1(2t)} + \cdots + a_{1(m)}Z_{1(mt)} + a_{2(0)}Z_{2(0t)} + a_{2(1)}Z_{2(1t)} + a_{2(2)}Z_{2(2t)} \\ + \cdots + a_{2(m)}Z_{2(mt)}\end{aligned} \tag{16}$$

After the value of a had been estimated from equation (16), the original *β* were estimated from equation (15) as follows:

$$\begin{gathered}\hat{\beta}_{i(0)} = \hat{a}_{1(0)} \\ \hat{\beta}_{i(1)} = \hat{a}_{1(0)} + \hat{a}_{1(1)} + \hat{a}_{1(2)} + \cdots + \hat{a}_{1(m)} \\ \hat{\beta}_{i(2)} = \hat{a}_{1(0)} + 2\hat{a}_{1(1)} + 4\hat{a}_{1(2)} + \cdots + i^m\hat{a}_{1(m)} \\ \hat{\beta}_{i(k)} = \hat{a}_{1(0)} + k\hat{a}_{1(1)} + k^2\hat{a}_{1(2)} + \cdots + k^m\hat{a}_{1(m)} \\ \hat{\beta}_{j(0)} = \hat{a}_{2(0)}\end{gathered} \tag{17}$$

$$\hat{\beta}_{j(1)} = \hat{a}_{2(0)} + \hat{a}_{2(1)} + \hat{a}_{2(2)} + \cdots + \hat{a}_{2(m)}$$
$$\hat{\beta}_{j(2)} = \hat{a}_{2(0)} + 2\hat{a}_{2(1)} + 4\hat{a}_{2(2)} + \cdots + j^m\hat{a}_{2(m)}$$
$$\hat{\beta}_{j(k)} = \hat{a}_{2(0)} + k\hat{a}_{2(1)} + k^2\hat{a}_{2(2)} + \cdots + k^m\hat{a}_{2(m)}$$

RESULTS

Determination of Currency Crisis Period

Determination of the crisis period was based on equations (5) and (6) above with a critical value of + 1.5 standard deviations. Therefore, the detected signal produces relatively accurate (the smaller the standard deviation, the more probability false signals will appear. Conversely, the greater the standard deviation, the smaller the signal appears, which could be good). Thus a period of the currency crisis in Indonesia was obtained, as shown in Table 2.

Table 2 Period of the Currency Crisis in Indonesia of 1991- 2019

Year	Month of Crisis	Frequency
1991	February	**1**
1994	March	**1**
1997	July, November, December	**3**
1998	January, May	**2**
2000	August	**1**
2001	January	**1**
2006	May	**1**
2008	September	**1**

Estimation Results of Vulnerability of Macroeconomic Indicators

The transformation was carried out on all data to obtain macroeconomic indicators on the currency crisis, as shown in Table 3.

Table 3 Macroeconomic Indicators of the Currency Crisis in Indonesia (1991-2019)

No	Early Indicator	A/A+C (%)	NSR	A/A+B %	(A+D)/ (A+B+C+D) %	Rank
1	Real Output	7,042	1,092	41,667	54,938	9
2	Stock price	5,634	1,365	36,364	54,321	13
3	Foreign exchange reserves	7,299	1,319	35,714	55,247	12
4	The difference in Domestic-Foreign Interest	13,380	0,082	90,476	61,420	2
5	Excess M1 Real Balance	8,451	1,300	37,500	53,704	11
6	M2 / Foreign Reserves	9,155	0,180	81,250	59,259	3
7	Bank Deposits	10,563	0,260	75,000	59,259	5
8	M2 Multiplier	8,451	1,040	42,857	54,938	8
9	Domestic Credit / GDP	8,451	0,780	50,000	56,173	7
10	Real Deposit Interest Rate	11,972	0,184	80,952	60,185	4
11	Loan / Deposit Interest Rates	4,930	1,449	35,000	54,321	15
12	Real Exchange Rates	15,493	0,071	91,667	62,346	1
13	Export	5,634	1,365	36,364	54,321	14
14	Import	7,042	1,092	41,667	54,938	10
15	Trade Exchange Rates	11,972	0,413	65,385	58,642	6

Description:
(A/A+C)(%) = Pre-crisis section that can be predicted accurately
NSR = Noise To Signal Ratio
(A/A+B)(%) = Conditional Probability of Crisis
(A+D)/(A+B+C+D)(%) = Accuracy of Prediction

The leading indicator was determined based on the four highest rankings as shown in table 3, and listed as follows: 1) Real Exchange Rate, 2) Difference in Domestic-Foreign Interest, 3) M2 / Foreign exchange reserves, and 4) Real Deposit Interest Rate.

Estimation Results By Involving Contagion Effect

The use of the Contagion Effect in predicting a currency crisis means involving the effects of the exchange rate crises in other countries into a particular nation's crisis. Meanwhile, the measurement also involved the value of the Contagion Effect, which was included in the composite index of the Leading Indicator, and It takes several steps to obtain it.

The weighting of Each Country's indicator on the Contagion Effect

The initial step was to determine the early indicators of each country (4 countries: South Korea, Malaysia, Philipines, Thailand) that affected the exchange rate crisis in Indonesia, which was by giving a binary number 1 when the country was in crisis, and a number 0 when there was none. Using the windows of the exchange rate crisis in Indonesia for 24 months showed each country's role by the same calculation when detecting a signal. The results are shown in Table 4:

Table 4 Indicator Signals of Each Country on Currency Crisis in Indonesia

Signal Accuracy	Kor	Mal	Phi	Tha
Noise To Signal Ratio (NSR)	0,668	0,468	0,284	0,087
The number of pre-crisis months that is precisely predicted	7	5	11	9
% Pre-crisis period giving a signal A / (A + C)	4,930	3,521	7,746	6,338
% False signal (B/B+D)	3,2967	1,6484	2,1978	0,5495
% Accuracy of Prediction (A+D)/(A+B+C+D)	56,481	56,790	58,333	58,642

Table 4 showed that the signals produced by each indicator had different weights between one country and another, which was reflected primarily by the magnitude of the NSR.

Estimation Results of Contagion Effect Index

Based on the assumption that countries with different currency crises had diverse effects on the currency crisis in Indonesia, then in the formation of the Contagion Effect index, the indicators were given different weights according to the size of the NSR of each country. The smaller the NSR, the greater the indicator value, and vice versa. The Contagion Effect Index was obtained from the aggregation of the weighting results of each nation. The results of the aggregation were visualized in Figure 1:

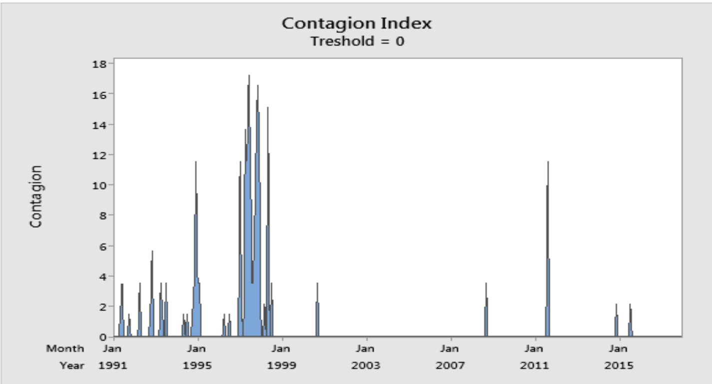

Figure 1 Contagion Effect Index

Estimation Results for Composite Index of Leading Indicator with Contagion Effect

The estimation results were obtained from the aggregation of the Leading Indicator with the Contagion Effect index, as visualized in Figure 2:

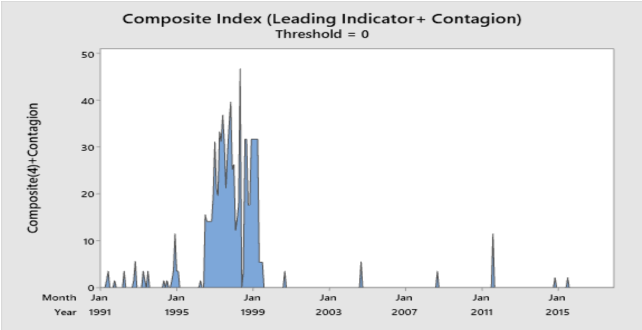

Figure 2 Composite Index (Leading Indicator and Contagion)

Signal generation results for the composite index of the Leading Indicator with Contagion Effect

Signal generation when the composite index exceeds the threshold, which was equal to + 1.5 standard deviations. Table 5 shows a comparison of signal generation results for the Composite Index of the Leading Indicator with or without the Contagion Effect.

Table 5 Comparison of Signal Generations for the Composite Index of Leading Indicator with or without Contagion Effect

Year	Signal of Leading Indicator (Month)	Total	Signal of Leading Indicator+ Contagion effect (Month)	Total
1996	7,8,9,10,11,12	6	7,12	2
1997	1,2,3,4,5,6,7,8,9,10,11	11	1,2,3,4,5,6,7,8,9,10,11,12	12
1998	1,4,5,8,9,10,11,12	8	1,4,5,8,9,10,11,12	8
1999	1,2,3,4	4	1,2,3,4	4
	Total	29	Total	26

Signal accuracy obtained from the composite index of Leading Indicator with or without contagion effect was shown in table 6.

Table 6 Comparison of Signal Accuracy for Composite Index of Leading Indicators with or without Contagion Effect

Signal Generation with Threshold = Mean + 1.5 Standard Deviations	**Leading Indicator**	**Leading Indicator +Contagion**
Noise To Signal Ratio (NSR)	**0**	**0**
The number of pre-crisis months that were precisely predicted	**29**	**26**
% Pre-crisis period giving a signal A / (A + C)	20,422	**28,571**
% False signal (B/B+D)	**0**	**0**
QPS	0,197	0,167
GBS	0,006	0,004
% Accuracy of Prediction(A+D)/(A+B+C+D)	65,123	**79,938**

Table 6 showed that the value of NSR = zero, which indicated no false signals in predicting the crisis. This was confirmed by the percentage of false signals (B / B + D) = zero. The number of pre-crisis months predicted correctly on the Leading Indicator with Contagion Effect was relatively less than without it, 29 compared to 26. However, there was an increase in the percentage of the pre-crisis period that gave the signal, which was 20.422% compared to 28.571%. This indicated that currency crises in other countries had an impact on the exchange rate crisis in Indonesia.

The signal performance also increased with the Contagion Effect, marked by QPS of 0.167, which was smaller than the previous by 0.197, and GBS of 0.004, which was lower than the previous by 0.006. The prediction accuracy of 79.938% was also higher than the previous by 65,123%.

EMPI Modeling Results

EMPI modeling as a function of Fundamental and Contagion effects is modeled using the Distributed-Lag model following the Weierstrass theory (Prinkus, 2000). It is assumed that β_i can be approximated by the Polynomial with the degree according to the lag length *i*.

Estimation Result of Distributed – Lag Polynomial with Fundamental (15) and Contagion effect as Explanatory Variable

Regression modeling with Distributed-Lag Polynomial (Gujarati, (2012) assumes that β_i *and* β_j were estimated by polynomials with an appropriate degree of i and j as lag length. Fundamental (15 macroeconomic indicators) and Contagion Effect as explanatory variables, and Exchange Rate Market Pressure Index (EMPI) as the dependent variable were shown in table 7 below:

Table 7 Backward Elimination of Terms

	------Step 1------		-------Step 2------	
	Coef	P	Coef	P
Constant	-0,01327		-0,01328	
Z0 (Fundamental 15 indicators)	0,00425	0,055	0,00460	0,000
Z1 (Fundamental 15 indicators)	0,00084	0,846		
Z2 (Fundamental 15 indicators)	-0,00139	0,318	-0,001130	0,001
Z0 (Contagion)	-0,00677	0,100	-0,00683	0,096
Z1 (Contagion)	0,01618	0,039	0,01646	0,033
Z2 (Contagion)	-0,00585	0,022	-0,00595	0,017
S		0,156032		0,155802
R-sq		5,81%		5,80%
R-sq(adj)		4,08%		4,36%
Mallows' Cp		7,00		5,04
AICc		-282,84		-284,90
BIC		-252,82		-258,59

Note: α to remove = 0,1

The above calculations showed that the estimation of step 2 produced a feasible model, which was better than step 1. It was indicated by several criteria, such as smaller Mallow Cp (*Cp*= 5,04 $\approx$ *p*=5), compared to step 1 (Cp = 7.00), and the AIC and BIC which produced lower values in step 2 (AIC = -284.90 and BIC = -258.59) than in step 1 (AIC = -282.84 and BIC = -252.82).

The estimation results from step 2 that had produced the most feasible model were then written in the form of the EMPI regression equation as a function of Z as follows:

Regression Equation

EMPI(Ind) = -0,01328 + 0,00460 Z0(Fund15) – 0,001130 Z2(Fund15) – 0,00683 Z0(Cont) + 0,01646 Z1(Cont) – 0,00595 Z2(Cont)

Based on the estimation, which was constructed in equation (17), the value of β_i *and* β_j were determined by the following calculations:

$\hat{\beta}_{i(0)} = \hat{a}_{1(0)}$= 0,00460

$\hat{\beta}_{i(1)} = \hat{a}_{1(0)} + \hat{a}_{1(1)} + \hat{a}_{1(2)}$ = 0,00347

$\hat{\beta}_{i(2)} = \hat{a}_{1(0)} + 2\hat{a}_{1(1)} + 4\hat{a}_{1(2)}$ = 0,00460 - 0,00452 = 0,00008

$\hat{\beta}_{i(3)} = \hat{a}_{1(0)} + 3\hat{a}_{1(1)} + 9\hat{a}_{1(2)}$= 0,00460 – 0,01017 = -0,00557 *(Eliminated)*

$\hat{\beta}_{j(0)} = \hat{a}_{2(0)}$ = 0,00683

$\hat{\beta}_{j(1)} = \hat{a}_{2(0)} + \hat{a}_{2(1)} + \hat{a}_{2(2)}$ = 0,00683 + 0,01646 – 0,00595 = 0,02924

$\hat{\beta}_{j(2)} = \hat{a}_{2(0)} + 2\hat{a}_{2(1)} + 4\hat{a}_{2(2)}$ = 0,00683 + 0,03292 – 0,0238 = 0,01595

$\hat{\beta}_{j(3)} = \hat{a}_{2(0)} + 3\hat{a}_{2(1)} + 9\hat{a}_{2(2)}$ = 0,00683 + 0,04938 – 0,05355 = 0,00266

After the values of β_i *and* β_j were determined, they were then substituted into equation (14), thus they were written as follows:

$$\widehat{Y_t} = -0{,}01328 + 0{,}00460\, X_{1(0)} + 0{,}00347 X_{1(t-1)} + 0{,}00008 X_{1(t-2)} + 0{,}00683 X_{2(0)} + 0{,}02924 X_{2(t-1)} + 0{,}01595 X_{2(t-2)} + 0{,}00266\, X_{2(t-3)}$$

where: $\widehat{Y_t}$ = EMPI estimation results, X_1 = *Fundamental* (15 macroeconomic indicators) and X_2 = *Contagion effect*.

Results of Analysis of Distributed – Lag Polynomial Estimation with Fundamental (Leading Indicator) and Contagion effect as Explanatory Variable

The results of regression analysis with the Distributed-Lag Polynomial with the Fundamental (Leading Indicator) and Contagion Effect as explanatory variables were shown in table 8 as follows:

Table 8 Backward Elimination of Terms

	------Step 1------		-------Step 2------		-------Step 3------		-------Step 4------	
	Coef	P	Coef	P	Coef	P	Coef	P
Constant	-0,01311		-0,01313		-0,01414		-0,01341	
Z0 (Fundamental 4 indicators)	0,00363	0,122	0,00487	0,000	0,00443	0,001	0,00451	0,001
Z1 (Fundamental 4 indicators)	0,00298	0,514						
Z2 (Fundamental 4 indicators)	-0,00210	0,153	-0,001174	0,002	-0,001095	0,003	-0,001085	0,004
Z0 (Contagion)	-0,00642	0,115	-0,00662	0,102				
Z1(Contagion)	0,01524	0,051	0,01613	0,036	0,00610	0,187		
Z2(Contagion)	-0,00551	0,030	-0,00585	0,019	-0,00318	0,089	-0,000753	0,022
S		0,155925		0,155788		0,156188		0,156366
R-sq		5,94%		5,82%		5,05%		4,54%
R-sq(adj)		4,21%		4,38%		3,89%		3,67%
Mallows' Cp		7,00		5,43		6,11		5,86
AICc		-283,30		-284,96		-284,33		-284,63
BIC		-253,28		-258,65		-261,74		-265,77

Note: α to remove = 0,1

The results from the above calculations showed that the estimation of step 4 produced a feasible model, which was better than steps 1, 2, and 3, and was characterized by several criteria, such as smaller Mallow Cp (Cp = 5.86), compared to steps 1 (Cp = 7.00) and 3 (Cp = 6.11). The others were AIC and BIC which produced smaller values in step 4 than in steps 1 (AIC = -283.30 and BIC = -253.28) and 3 (AIC = -284.33 and BIC = -261, 74). Step 2 produced Mallow Cp criteria that were lower than step 4 (Cp = 5.43), and smaller AIC figures (AIC = -284.96), but greater BIC values (BIC = -258, 65), moreover the estimation results in step 2 still produced insignificant coefficient figures.

The estimation results from step 4 produced the most feasible model. Then the regression equation was written using EMPI and Z data as follows:

EMPI(Ind) = -0,01341 + 0,00451 Z0(Fund(4)) – 0,001085 Z2(Fund(4)) – 0,000753 Z2(Cont)

Based on the estimation, *a* which was constructed as in equation (17), the value of β_i *and* β_j were determined as follows:

$\hat{\beta}_{i(0)} = \hat{a}_{1(0)}$= 0,00451
$\hat{\beta}_{i(1)} = \hat{a}_{1(0)} + \hat{a}_{1(1)} + \hat{a}_{1(2)}$ = 0,00451- 0,001085 = 0,003425
$\hat{\beta}_{i(2)} = \hat{a}_{1(0)} + 2\hat{a}_{1(1)} + 4\hat{a}_{1(2)}$ = 0,00451 – 0,00434 = 0,00017
$\hat{\beta}_{i(3)} = \hat{a}_{1(0)} + 3\hat{a}_{1(1)} + 9\hat{a}_{1(2)}$= 0,00451 – 0,009765 = -0,005255 *(Eliminated)*
$\hat{\beta}_{j(0)} = \hat{a}_{2(0)}$ = 0 *(Eliminated)*
$\hat{\beta}_{j(1)} = \hat{a}_{2(0)} + \hat{a}_{2(1)} + \hat{a}_{2(2)}$ = -0,000753 *(Eliminated)*

After the value of β_i *and* β_j were determined, they were then substituted into equation (9). Thus they were written as follows.

$$\widehat{Y_t} = -0{,}01341 + 0{,}00451\,X_{1(0)} + 0{,}003425X_{1(t-1)} + 0{,}00017X_{1(t-2)}$$

where: $\widehat{Y_t}$ = EMPI estimation results, X_1 = *Fundamental* (*Leading Indicator)* and X_2 = *Contagion effect*.

DISCUSSIONS

The determination of the Leading Indicators are based on the four highest rankings of macroeconomic indicators and are listed as follows: 1) Real Exchange Rate, 2) Difference in Domestic-Foreign Interest, 3) M2 / Foreign Reserves, and 4) Real Deposit Interest Rate. Signals generated using the composite Index of Leading Indicators with or without the Contagion Effect do not produce false signals in predicting a crisis. An increase in the percentage of the pre-crisis period with the Contagion Effect indicates that a currency crisis in other countries can impact the exchange rate crisis in Indonesia in the future. The signal performance also increases with the Contagion Effect, marked by QPS and GBS, smaller than the previous.

When the contribution of the Fundamental and Contagion effect to EMPI is modeled in a regression function with cross-section data, it does not produce an adequate model due to the time gap between the explanatory variables.

The results involving Fundamental (15 indicators) and Contagion Effect in the Distributed–Lag Polynomial show that the Fundamental contributed significantly to EMPI since time is t-2, while Contagion Effect contributed significantly to t-3. Therefore, the closer the time t coefficient of each explanatory variable, the higher the value. The same approach using Fundamental (4 Leading Indicators) and Contagion Effects as the explanatory variables shows that the Fundamental has significant contributions to EMPI for the time t-2. At the same time, Contagion Effect does not contribute significantly, and as a result, it is eliminated from the regression function or the leading indicators. Therefore the Fundamental variables have more significant dominance on EMPI behavior.

Modeling results can be compared to the role of using indicators in the model. Using more indicators produces more information because the signals generated can detect certain sectors that need improvement. However, more data is needed to obtain these indicators, which may already be represented by other indicators. Furthermore, there are likely to be many indicators that contribute to forming a small signal, leading to inefficiency. Using fewer indicators, there is ease in obtaining data. Hence it is more efficient, practical in terms of modeling and speeds up concluding. However, there is little data, which causes relatively limited information to be absorbed. This means the sectors that need attention may not be detected properly.

The estimates produced in this study can detect initial shocks, indicating when the exchange rate crisis began. This can help policymakers take immediate action to anticipate whether the crisis will recur or mitigate it. The policies related to the exchange rate have significant impacts on the economy (Lim and Dash, 2021).

CONCLUSIONS

Leading Indicators as Fundamental factors have a dominant effect of generating the crisis signals. When modeling more macroeconomic indicators, the crisis signal is divided into each indicator, which does not necessarily contribute significantly to a currency crisis. The same thing happened to the contagion effect, which contributed to the crisis model. The model shows that the initial shock of the macroeconomic indicators starts from t-2, while the contagion effect starts from t-3. In case the leading indicator is fundamental, the contagion effect will be insignificant. This means that the model is more dominantly influenced by fundamental factors, where the initial shock starts at t-2.

According to Minsky's (1992) approach, the existence of an initial check a few months before the onset of the crisis gives policyholders time to map and anticipate the possibility of a worse crisis.

Currency crisis modeling as a function of Fundamental and Contagion effects is more representative using the Distributed-Lag Polynomial approach than cross-sectional study. Modeling trials using cross-section data did not produce a viable model. This implies that the occurrence of a currency crisis was not solely caused by current macroeconomic indicators. It was motivated by macroeconomic indicators in the past.

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