

Predicting Currency Crises: How do Indicators Differ According to Crisis Definition?

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Abstract

The focus of this paper is currency crisis, particularly the evaluation of the models that attempt to forecast currency crisis. Here, the aim is to investigate the impacts of definition differences on Early Warning Systems. In order to show that significances of the crisis indicators are dependent to crisis definitions of the models, the significant variables for the models that are constructed with the depreciation based definition of Reinhart and Rogoff (2009) and Exchange Market Pressure Index based definition of Eichengreen et al. (1996) are separately identified. The results of the estimations of the models that are constructed with these different approaches have shown that, different definition methods identify different sets of variables as crisis indicators.

Keywords: Currency Crisis, Early Warning System, Probability Threshold, Crisis Prediction

JEL Code: E47, E60, F31, F37

Döviz Krizlerinin Tahmini: Kriz Tanımına Göre Kriz Emareleri Nasıl Farklılık Gösteriyor?

Öz

Bu çalışmanın odağında döviz krizleri bulunmakta ve döviz krizlerinin tahmininde kullanılan modeller değerlendirilmektedir. Daha özeldede ise bu çalışma kriz tanımının Erken Uyarı Sistemleri üzerindeki etkilerini incelemektedir. Kriz emarelerinin krizin tanımlanmasına bağlı olduğunu ve bu tanımlara göre farklı değişkenlerin anlamlı kriz emareleri olarak belirlendiğini ispatlamak için literatürde yaygın bir şekilde kullanılan iki ana döviz krizi tanımını kullanarak (Reinhart ve Rogoff (2009) ve Eichengreen vd. (1996)) farklı Erken Uyarı Modelleri oluşturuldu. Sonuçlar gerçekten de diğer tüm değişkenler sabit tutulmasına rağmen kriz tanımlarından dolayı farklı değişkenlerin kriz sinyalleri olarak istatistiksel olarak anlam kazandığını gösterdiler.

Anahtar Kelimeler: Döviz Krizleri, Erken Uyarı Sistemleri, Olasılık Eşiği, Kriz Tahmini

JEL Kodları: E47, E60, F31, F3

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1. Introduction

Among all types of economic crisis, currency crisis come to the forefront due to its frequency and destructive impacts on economies. Currency crises are generally the first and the most visible sign of serious macroeconomic and balance of payments imbalances. They are very often associated with banking and sovereign crises. Moreover, the sudden adjustment of relative prices often leads to significant losses on public and private balance sheets. A currency crisis is typically followed by a substantial growth slow-down or a contraction (Frost and Saiki, 2013).

Wide ranges of currency crisis have shown that currency crises are epidemic and have contagious effect. In this kind of situation, in order to overcome an incoming crisis, the best option would be having a mechanism to foresee the possible future crisis and to take early precautions. Today, academics and wide range of practitioners believe that this can be achieved by constructing a solid Early Warning System (EWS). Early Warning System (EWS) is a tool to detect underlying economic weaknesses and vulnerabilities and to anticipate whether and when countries may be affected by an economic crisis.

Early Warning System uses a precise definition of a crisis to identify the significant crisis indicators and to generate predictions of crises. In this paper, in order to show that significances of the crisis indicators are dependent to crisis definitions of the models, the significant variables for the models that are constructed with the depreciation based definition of Reinhart and Rogoff (2009) and Exchange Market Pressure Index based definition of Eichengreen et al. (1996) are separately identified. In this study the significant variables among a list of real sector, financial sector and balance of payments variables, and debt profile of economies were identified.

The paper is organized as following. In the next section, brief literature of EWS is given in two parts. The concept of EWS is described in the third section. Section 4 discusses the empirical framework and reveals the results obtained. Finally, the last section concludes this study.

2. Previous Research

In the literature, currency crises are defined in multiple ways which add up to vast currency crisis literature.

Table 1: Currency Crisis Definitions in Selected Literature

	Currency Crisis Definition	Time Period	Country Set
Eichengreen, Rose, and Wyplosz (1994)	Eichengreen, Rose, and Wyplosz (1994) Their exchange market pressure is based on change in exchange rate, change in reserves and the change in interest rate. They define currency crisis if this index exceeds its mean by 1.5 standard deviations.	1959-1993	20 Developed Countries
Frankel and Rose (1996)	They define currency crisis as a nominal depreciation of 25 percent or greater, which is at least 10 percent greater than the depreciation in the preceding year.	1971-1992	105 Developing Countries
Sachs, Tornell, Velasco (1996)	They construct a crisis index as a weighted average of the devaluation rate with respect to US dollar and percentage change in foreign exchange reserves	1989-1994	20 Emerging Countries
Kaminsky, Lizondo, Reinhart (1998)	Crisis are identified by EMP index. This index is weighted average of monthly percentage changes in the exchange rate (units of domestic currency per US dollar or per Deutsche mark, depending on which is relevant) and the negative of monthly percentage changes in gross international reserves (in dollars). Periods where index is above its mean more than three standard deviations are defined as crisis.	1970-1995	15 Developing, 5 Developed Countries
Kruger, Osakwe, Page (1998)	They define EMP as a weighted average of percentage changes in the nominal exchange rate and negative of percentage changes in international reserves. They define crisis if this index is 1.5 standard deviations above the mean.	1977-1993	19 developing countries
Larrain, Esquivel (1998)	They consider that currency crisis exists when there is an abrupt change in the nominal exchange rate. First, they say there exist a currency crisis if the accumulated three month real exchange rate changes is 15 percent or more. Second, they say there is a currency crisis if one month change in the real exchange rate is higher than 2.54 times the country specific standard deviation of the real exchange rate monthly growth rate, provided that it also exceeds four percent.	1975-1996	30 countries
Milesi-Ferretti, Razin (1998)	Milesi-Ferretti and Razin (1998) use a definition that requires, in addition to 25 percent depreciation, at least a doubling in the rate of depreciation with respect to the previous year and a rate of depreciation the previous year below 40 percent. To restrict the sample to episodes in which the exchange rate was relatively stable the previous year, another definition they employ requires a 15 percent minimum rate of depreciation, a minimum 10 percent increase in the rate of depreciation with respect to the previous year, and a rate of depreciation of below 10 percentage points in the previous year.	1970-1996	105 Low and Middle Income Countries

Table 1 (continued)

Berg, Pattillo (1998)	They use currency crisis definitions of KLR, Frankel Rose and STV	1970-1995	20 countries
Aziz, Caramazza, Salgado (2000)	They construct FEMP index as a weighted average of monthly exchange rate changes and reserve changes. Currency crisis occurs if this index exceed a specified threshold which is 1,5 times the pooled standard deviation of the calculated index plus the pooled mean of the index.	1975-1997	50 countries
Edison (2000)	The index is calculated as the weighted average of percent changes in the bilateral nominal exchange rate and the percent change in foreign reserves. If this index exceeds the mean by 2.5 standard deviations, then currency crisis occurs.	1970-1995	Signal Approach
Bussiere and Fratzscher (2002)	EMP is a weighted average of the change of the real effective exchange rate, the change in the interest rate and the change in foreign exchange reserves. Currency crisis occurs if this index is above the mean by 2 standard deviations.	1993-2001	32 Countries
Reinhart and Rogoff (2009)	An annual depreciation versus US dollar (or the relevant anchor currency) of 15% or more	1800-2006	70 Countries
Budsayaplakorn, Dibooglu, Mathur (2010)	Crisis identified by the behavior of an index called FEMP. This index is the weighted average of quarterly change percentage in exchange rate and percentage change in gross international reserves. A currency crisis is defined to occur when the index of exchange market pressure exceeds the mean by more than 2 standard deviations.	1975-1997	5 countries
Candelon, Dumitrescu and Hurlin (2010)	EMP index is comprised of change in exchange rate, interest rate and foreign reserves. Currency crisis occurs if this index is more than 2 standard deviation plus mean of the index.	1985-2008	15 Emerging Countries

However, it is possible to group those definitions under two main groups; definitions that are based on depreciation rate and definitions that use Exchange Market Pressure (EMP) Index. For this reason, in an attempt to reveal the definition differences more explicitly, the related literature is divided into two separate sections with respect to definition description: depreciation based definitions and Exchange Market Pressure Index based definitions.

2.1 Depreciation Rate Based Definitions

Frankel and Rose (1996) conduct a study in order to arrive a comprehensive statistical characterization of currency crisis and to find an answer whether the currency crisis can be predicted ex ante with standard economic indicators in developing countries. For this aim, they define a currency crisis as at least 25 percent nominal depreciation of currency for the current year and 10 percent more than the previous year's depreciation rate. In order to avoid counting the same crisis

twice, they include crises that are at least 3 years apart. They consider more than 100 developing countries for the period of 1971-1992. They find that currency crashes occur when foreign direct investment inflows dry up, reserves are low, domestic credit growth is high, interest rates are rising, and the real exchange rate shows overvaluation. They observe that current account and government budget do not have significant effects on a currency crash.

Milesi-Ferretti and Razin (1998) extend the work done by Frankel and Rose (1996). In this study, they investigate the factors to predict the currency crisis and the impact of currency crisis on economic performance. For this purpose, they use four different currency crisis definitions in their study. The first definition is the same with Frankel and Rose (1996). They state that this definition captures large exchange rate fluctuations associated with high inflation episodes. Their second currency defines the crisis as in addition to 25 percent depreciation for the current year, depreciation rate should at least double with respect to the previous year and a rate of depreciation of the previous year should be below 40 percent. According to the third definition, for crisis to be present there should be at least 15 percent of depreciation, which should be at least 10 percent more than previous years' and the rate of depreciation of previous year should be less than 10 percent. The fourth definition defines the crisis the same with the third one but adds that the exchange rate should be pegged the year before the crisis. Milesi-Ferretti and Razin (1998) consider 105 countries (48 African countries, 26 Asian countries, 6 Latin American and Caribbean countries and 5 European countries) over the period between 1970 and 1996 and they use probit model. They find that low reserves, appreciated real exchange rate, high interest rate when the external conditions are unfavorable and low growth in industrial countries cause currency crisis.

Reinhart and Rogoff (2009) offer a detailed quantitative overview of the history of financial crisis dating from the mid-fourteenth century default of Edward III. In this comprehensive study, they are interested in both dating and duration of the currency crisis. The scholars define the currency crisis by following Frankel and Rose (1996) who focus on the rate of depreciation. According to that, they define the period as a crisis period if an annual depreciation of national currency versus US dollar (or the relevant anchor currency) is 15% or more. For their study, Reinhart and Rogoff (2009) cover the period between the years of 1800-2008 for 69 countries from Africa, Asia, Europe, Latin America, North America, and Oceania. They conclude that, the largest crashes are similar in timing and orders of magnitudes as the inflation profile.

2.2 Exchange Market Pressure Index Based Definitions

In an early study, Girton and Roper (1977) combine the changes in exchange rates and foreign exchange reserves and build the very first Exchange Market Pressure

Index. Following this study, EMP Index becomes a preferred index that is used in EWS models by academics, policymakers and economists.

Eichengreen et al. (1996) take the EMP model of Girton and Roper (1977) and utilize it in their work. In their study, they aim to analyze the contagious nature of currency crises. With this aim, they construct an Exchange Market Pressure Index which is based on change in exchange rate, change in reserves and change in interest rate. They accept the presence of a currency crisis if this index exceeds the mean by 1.5 standard deviations. Scholars consider 20 industrialized economies for the years between 1959 and 1993. By using probit model they find that contagion appears to spread more easily to countries which are tied by international trade linkages compared to countries in similar macroeconomic circumstances.

One of the most important studies in the literature is done Kaminsky et al. (1998). In their study, they construct EMP Index with weighted average of monthly percentage changes in the exchange rate (units of domestic currency per US dollar or per Deutsche mark, depending on which is relevant) and the negative of monthly percentage changes in gross international reserves (in dollars). Periods where index is above its mean more than three standard deviations are defined as crisis. They use 15 developing and 5 developed countries between the years of 1970-1995. With this work, Kaminsky et al. (1998) bring a new technique for Early Warning System which is called the signal approach. According to this non-parametric method, the indicators are identified by their non-normal behavior. Furthermore, with this study, the term a false signal or noise has introduced to literature. If an indicator sends a signal and there is a crisis then this is a good signal but if there is no crisis after the signal, then it is called a false signal or noise. They find that international reserves, the real exchange rate, domestic credit, credit to public sector and domestic inflation are the particularly useful indicators in anticipating the currency crisis.

In 1998, Kruger et al. investigate whether the macroeconomic variables, measure of lending booms, real exchange rate misalignment and the ratio of M2 to international reserves that are seen as causes of currency crises are the only determinants of the currency crises. For this aim, they use EMP Index in order to define currency crises. They define EMP Index as a weighted average of percentage changes in the nominal exchange rate and negative of percentage changes in international reserves. If the index is 1.5 standard deviations above the mean, they accept the presence of the crisis. In their study they make a sensitivity analysis by changing the standard deviation to 1. They note that this change increase the number of crisis in the sample from 23 to 39 and also the number of significant variables. They use probit model with 50% threshold for 19 developing countries in order to examine the determinants of currency crises in developing countries. They conclude that lending booms, real exchange rate misalignment and reserve inadequacy increase the probability of a speculative attack on a currency.

Goldstein et al. (2000) analyze early warning indicators of banking and currency crisis. In this study, they define currency crisis as a weighted average of changes in the exchange rate and in foreign exchange reserves. They accept the presence of currency crisis if this index is more than 3 standard deviations from its mean. Their country set is comprised of 25 emerging countries for the time period of 1970-1995. By using a signal approach, they find the same indicators significant with Kaminsky et al. (1998). However, they include that banking crisis is also important in the context of predicting currency crisis.

Bussiere and Fratzscher (2002) set a broad set of economic and financial indicators in their study to test the role of indicators and they develop a methodology for the correction of the post crisis bias. By developing a multinomial logit regression model they distinguish tranquil, crisis and post-crisis periods. They define currency crisis based on EMP, which is weighted average of the change of the real effective exchange rate, the change in the interest rate and the change in foreign exchange reserves. They accept the presence of the crisis if index is above the mean by 2 standard deviations. They investigate 20 countries between the time period 1993-2001. They obtain that multinomial logit regression has more success ratio than logistic model in terms of correctly predicting the currency crises. After Bussiere and Fratzscher (2002), in the Early Warning System literature, multinomial logit model is started to be preferred instead of binomial logit model.

Paltonen (2006) compares artificial neural network (ANN) model with probit model. They define the currency crisis based on EMP index. Paltonen (2006) constructs the index with the percentage change of the price of US dollar on a country's currency and percentage change in the level of the country's foreign reserves and accepts the presence of the crisis if this index is above its mean by 2 standard deviations. By investigating a country set that includes 24 countries between the periods 1980-2001 he finds that ANN model outperforms probit model; but eventually, both models show poor results in the prediction of the currency crisis.

Comelli (2013) compares parametric and non-parametric EWS prediction in sample and out of sample currency crisis in emerging market economies between the years of 1995-2011. He defines the currency crisis using EMP index which is a weighted average of one-month change in the exchange rate and foreign exchange reserves and accepts the presence of the crisis if the index is more than three standard deviations above the mean. He uses a fixed effects logit model in order to predict the currency crises. As a result, the scholar finds that parametric EWS achieves superior out of sample results compared to non-parametric EWS.

3. An Overview Of EWS

The estimation techniques of Early Warning Systems can be categorized under two groups as Parametric and Non-Parametric Approaches. In this study the parametric approach is taken into consideration and logistic regression is used as an estimation technique.

Early Warning System is modelled as a binomial choice model where dependent variable takes the value of 1 when a crisis is said to occur and 0 when there is no crisis. The model explains the probability of a crisis as a function of explanatory variables (crisis indicator) which describe the economic, political and social condition of the country. The parametric logit estimation gives an opportunity to observe whether the explanatory variables that included in the model is significant explanatory power and have a predictive power for the probability of a possible future crisis.

In binary choice models, if the considered event occurs, the dependent variable takes the value 1 and 0 otherwise. In this study $P_{i,t}$ is the probability of the the currency crisis and $(1- P_{i,t})$ is otherwise. $y_{i,t}=1$ implies that country i has experienced a currency crisis in time t and $y_{i,t}=0$ otherwise. $E(y_{i,t})$ is the expected value of the crisis variables which is equal to the probability of crisis occurrence and is modeled by:

$$E(y_{i,t}) = 1 \cdot p_{i,t} + 0 \cdot (1 - p_{i,t}) = p_{i,t} \quad (1)$$

which is generally modeled as a function of some explanatory variables:

$$P_{i,t} = \Pr(Y_{i,t} = 1) = E(Y_{i,t} | X_{i,t}) = f(X'_{i,t}\beta) \quad (2)$$

As a binary choice model, logistic regression is used relying on the advantages such as; allowing properties of a linear regression model to be exploited, can take the values between $-\infty$ and $+\infty$ whereas the probability remains constrained between 0-1 and directly related to odds ratio (the changes in the model can totally be reflected to the ratio).

Logistic regression measures the relationship between a dependent variable and one or more independent variables by using probability scores as the predicted values of the dependent variable.

Logistic function is used for the explanation of the logistic regression which can be given as follows:

$$P_i = e(Y = 1 | X_i) = \frac{1}{1 + e^{-x_i\beta_j}} \quad (3)$$

where j is the linear function of the explanatory variable x and the logistic function is:

$$P_i = \frac{1}{1 + e^{-z_i}} = \frac{e^z}{1 + e^z} \quad \text{where } z_i = X_i\beta_j \quad (4)$$

which is interpreted as the probability of occurrence of the event. Additionally, β_0 is the intercept from the linear equation, $\beta_1 x$ is the regression coefficient multiplied by the predictor and e is the exponential term.

The main hypothesis of this study is that how you define a currency crisis has important repercussion for the success of the EWS model. Thus, the purpose of this paper is to determine the significant explanatory variables and the most relevant economic conditions that explain the probability of a currency crisis. Our aim is to find a broad set of explanatory variables that is relevant for both type of definition approaches of currency crisis.

In the literature there are two prominent approaches in defining the occurrence of a currency crisis. The first one is based on the rate of depreciation of the domestic currency. The second one is based on an indicator generally referred to as Exchange Market Pressure Index. While the Depreciation Based Currency Crisis definitions recognizes a currency crisis based on changes in the depreciation rate, Exchange Market Pressure index based definitions usually comprised of combinations of different variables.

3.1 Depreciation Rate Based Currency Crisis Definition (Reinhart and Rogoff, 2009):

Reinhart and Rogoff (2009) define currency crisis based on depreciation rate of the local currency against a relevant anchor currency instead of designing an index. They consider a country is exposed to a currency crisis if an annual depreciation of national currency versus US Dollar (or relevant anchor currency) is 15% or more (Reinhart and Rogoff, 2009). According to this binary variable takes the value 1 if the annual depreciation rate of a country's national currency versus US Dollar is 15% or more, and 0 otherwise.

3.2 Exchange Market Pressure Index Based Currency Crisis Definition (Eichengreen et al., 1996):

Eichengreen et al. (1996) construct an Exchange Market Pressure Index which is the weighted average of the exchange rates changes ($\% \Delta e$), international reserves changes ($\% \Delta r$) and interest rate changes ($\% \Delta i$). The EMP Index can be shown as:

$$EMP_{i,t} = [(\alpha \% \Delta e_{i,t}) + (\beta \Delta(i_{i,t} - i_t^*)) - (\gamma (\% \Delta r_{i,t} - \% \Delta r_t^*))] \quad (1)$$

where $e_{i,t}$ is the exchange rate of domestic currency relative to US Dollar at time t , $\Delta(i_{i,t} - i_t^*)$ is the variation in the spread between domestic interest rates and US interest rate and $(\% \Delta r_{i,t} - \% \Delta r_t^*)$ is the percentage change in spread of international reserves¹ that is abroad and at home.

According to Eichengreen et al. (1996) currency crisis definition, binary variable (currency crisis) takes the value 1 if EMP exceeds its mean by 1.5 standard deviation and stated as crisis. Otherwise, binary variable takes the value 0, meaning that there is no currency crisis and the country is in non-crisis period.

4. Empirical Framework

In this paper, the same country data set with Reinhart and Rogoff (2009) which consists of 69 countries² from six different regions is used. The country set is given in Table 1.

Table 2: Country Set

Region	Countries
Africa	Algeria, Angola, Central African Republic, Cote D'Ivoire, Egypt, Ghana, Kenya, Mauritius, Morocco, Nigeria, South Africa, Tunisia, Zambia, Zimbabwe
Asia	China, India, Indonesia, Japan, Korea, Malaysia, Myanmar, Philippines, Singapore, Sri Lanka, Thailand
Europe	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Romania, Russia, Spain, Sweden, Switzerland, Turkey, United Kingdom
Latin America	Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, Venezuela
North America	Canada, United States
Oceania	Australia, New Zealand

¹ r is the ratio of reserves to narrow money (M1)

² Except from Taiwan because of the data availability.

The time period is set as 1970-2010 with annual observations. In total, 35 explanatory variables are chosen. These indicators are classified in 8 groups as Capital Account Variables, Debt Profile Variables, Current Account Variables, International Variables, Financial Liberalization Variables, Other Financial Variables, Real Sector Variables, and Institutional/Structural Factors by following Kaminsky et al. (1998). The data are drawn from World Bank and IMF-IFS database and the empirical analysis is performed by using the software package Stata 11. The list of the explanatory variables is given in Table 2.

Table 3: Explanatory Variable Categories and the List of Variables³

Variable Category	Variables
Capital Account	Net Foreign Direct Investment, The Ratio of Foreign Direct Investment to GDP, Portfolio Equity Net Inflows
Debt Profile	Short-term Debt (% of Total Reserves), Public and publicly guaranteed debt service (% of GNI), Multilateral Debt Service (% of Public and Publicly Guaranteed Debt Service), Interest Payment on Total External Debt (% of GNI), Total External Debt Stocks (% of GNI), Domestic credit to private sector by banks (% of GDP), Domestic Credit to Private Sector (% of GDP), Total reserves (% of total external debt), The Ratio of External Debt to GDP, Short-term debt (% of total external debt), Private non-guaranteed external debt stocks, Public and publicly guaranteed external debt stocks
Current Account	Real Effective Exchange Rate, Current account balance (% of GDP), Export growth (% annual growth), Import Growth (% annual growth)
International Variables	Use of IMF credit, Foreign Exchange Reserves
Financial Liberalization	Risk Premium on lending, Deposit interest rates, real interest rate
Other Financial Variables	The Ratio of M2 to GDP, M2 (% of GDP)
Real Sector	Inflation Rate, GDP per Capita Growth, Unemployment Rate, Gross Savings (% of GDP)
Institutional/Structural Factors	Degree of Openness for Trade

Using the sample which consists of annual data of 69 countries for the period 1970-2010, whether information on variables on real sector, financial liberalization

³ Definitions of the variables are directly taken from the World Bank, World Development Indicators Data and calculated accordingly.

conditions, other financial sector information, current account, debt profile, capital account, and international economic conditions has explanatory power on the currency crisis is examined. In the first stage of empirical analysis, logit estimations using combinations of various explanatory factors are conducted. In the initial estimations it is seen that 11 explanatory variables⁴ have some effect on either one or both of the dependent variables used as binomial crisis variable defined according to two alternative definitions.

After the elimination of the explanatory variables, the analysis can be done for the models where the crisis definitions of Reinhart and Rogoff (2009) and Eichengreen et al. (1996) are used as dependent variables. In the first category various variables for the real sector and economic conditions which are GDP per capita growth, net national savings and inflation rate are used. As a next step, in addition to these variables, some other variables for financial sector and financial liberalization are added. These are deposit interest rate, the ratio of M2 to international reserves. As a measure of countries' competitiveness, real effective exchange rate; as measures of debt profile, public and publicly guaranteed external debt stocks, domestic credit provided by banking sector (% of GDP) and total reserves (% of total external debt) are included into estimations. Furthermore, as a measure of capital account; the ratio of FDI to GDP, portfolio equity net inflows (BoP, current US\$) are included into models. In the final step, the explanatory variable set that constitutes only the significant variables for each EWS models are obtained.

In sections 4.1 and 4.2, the results of this empirical analysis are reported. While Section 4.1 presents the models where currency crisis is defined according to the rate of depreciation of nominal exchange rate, Section 4.2 summarizes empirical results of the models where EMP Index is used as a crisis definition.

4.1 Nominal Exchange Rate Depreciation-Based Crisis Definition

Table 4 below presents the empirical results of the logistic regressions for the model where nominal depreciation rate is above 15%.

The table reports results of regressions for Model 1 to Model 7, where each model is constructed by separately adding each group of explanatory variable into the estimation.

⁴ GDP per Capita Growth, Inflation Rate, Net National Savings (% of GNI), the Ratio of M2 to International Reserves, Deposit Interest Rate, Real Effective Exchange Rate, Domestic Credit Provided by Banking Sector, Public and Publicly Guaranteed External Debt Stocks, Total Reserves (% of Total External Debt), the Ratio of Foreign Direct Investment to GDP, Portfolio Equity Net Inflows

Table 4: Empirical Results of the Models that constructed with Reinhart and Rogoff (2009) Currency Crisis Definition

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Final
GDP per Capita Growth	-0.000380*** (-2.75)	-0.000359** (-2.55)	-0.000371** (-2.45)	-0.000371** (-2.43)	-0.000348* (-1.75)	-0.000354* (-1.78)	-0.000394* (-1.71)	-0.000272** (-2.25)
Net National Savings	0.0000115 (0.07)	0.0000437 (0.26)	-0.000101 (-0.56)	-0.0000719 (-0.39)	-0.000390 (-1.62)	-0.000387 (-1.60)	-0.000373 (-1.48)	
Inflation Rate	-0.0000237 (-0.15)	0.0000365 (0.23)	0.000131 (0.77)	0.000146 (0.86)	0.000345 (1.50)	0.000348 (1.51)	0.000433* (1.76)	0.000123 (0.90)
The Ratio of M2 to International Reserves		-0.00109*** (-4.05)	-0.00123*** (-4.27)	-0.00124*** (-4.32)	-0.00237*** (-5.15)	-0.00242*** (-5.00)	-0.00279*** (-5.11)	-0.000947*** (-4.05)
Deposit Interest Rate			-0.000423 (-1.47)	-0.000439 (-1.52)	-0.000512 (-1.34)	-0.000510 (-1.34)	-0.000490 (-1.24)	
Real Effective Exchange Rate				0.000726* (1.87)	0.00117* (1.82)	0.00117* (1.82)	0.00121* (1.81)	0.000127 (0.50)
Domestic Credit Provided by Banking Sector (% of GDP)					0.00110*** (2.66)	0.00111*** (2.67)	0.00149*** (3.10)	0.000251 (1.39)
Public and Publicly Guaranteed External Debt Stocks					-0.000147 (-0.33)	-0.000146 (-0.33)	-0.000217 (-0.46)	
Total Reserves (% of Total External Debt)					-0.000481 (-1.49)	-0.000465 (-1.43)	-0.000480 (-1.36)	
The Ratio of Foreign Direct Investment to GDP						0.0000992 (0.37)	0.000116 (0.40)	
Portfolio Equity Net Inflows							0.000217 (0.38)	
<i>N</i>	1285	1285	987	987	567	567	520	1662
<i>Log Likelihood</i>	-293.80857	-284.8354	-241.67062	-239.8232	-145.17786	-145.11027	-131.68731	-379.47408
<i>LR chi2</i>	7.71	25.66	30.83	34.52	51.32	51.45	52.60	25.09
<i>Prob > chi2</i>	0.0523	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Estimates are fixed effect panel estimation results

Using a nonparametric bootstrap, Stata provides a heteroscedasticity robust covariance

According to the results, GDP per capita growth is a significant indicator of currency crisis. It is significant in all models and it keeps its significance in the final model too. As it is expected GDP per capita growth has a negative sign, meaning that increasing values of this variable decreases the possibility of a currency crisis. Inflation rate yields insignificant results in all models except the Model 7. In Model 7, the inflation rate is significant at 10% level with positive sign. Therefore, an increase in inflation increases the probability of the currency crisis.

The ratio of M2 to international reserves is also a significant indicator of currency crisis. The final model that is constructed with the combination of significant

explanatory variables from previous models too confirms the significance of this variable on explaining the currency crisis. In all regressions, it is significant at 1% level. The results show that there is a negative relationship between the ratio of M2 to international reserves and occurrence of currency crisis. Therefore, the probability of currency crisis decreases with increasing values of the ratio of M2 to international reserves.

The variables domestic credit to banking sector and real effective exchange rate are significant crisis indicators according to Models 4, 5, 6, and 7. Positive signs of those variables show that with increasing value of domestic credit to banking sector and real effective exchange rate, the possibility of currency crisis increases. However, an interesting outcome is that when those variables are combined with GDP per capita growth and the ratio of M2 to international reserves in the final model, they do not show significant results anymore.

The variables net national savings, deposit interest rate, public and publicly guaranteed external debt stocks, total reserves (% of total external debt), the ratio of foreign direct investment to GDP and portfolio equity net inflows are not significant at any significance levels in any of the models.

To sum up, regression results show that among real sector variables, only GDP per capita growth is a significant indicator of currency crisis. The sign of the coefficient shows that the higher the GDP per capita growth rate the lower will be the probability of a currency crisis. Other factors that are found to be important in explaining the probability of currency crisis are inflation, the ratio of M2 to international reserves, real effective exchange rate, and domestic credit provided by banking sector (% of GDP). An increase in inflation increases the probability of a currency crisis as expected. The monetary expansion compared to the international reserves seems to have a decreasing effect on the probability of a currency crisis. Furthermore, an increase in real effective exchange rate increases the probability of the crisis. Lastly, the results imply that an increase in the domestic credit provided in the banking sector (% of GDP) increases the probability of the currency crisis. The final model is constructed by using only the significant variables from previous regressions. In this final regression, two variables which are GDP growth per capital and the ratio of M2 to international reserves are found significant.

4.2 Exchange Market Pressure Index-based Crisis Definition

The below table presents the empirical result of the logistic regression for a model that constructed with Eichengreen et al. (1996) currency crisis definition. As it is in the previous analysis, there are 7 models with different sets of explanatory variables. The final regression is conducted with the explanatory variables that are significant in other previous models.

Table 5: Empirical Results for the Models according to Eichengreen et al. (1996) Currency Crisis Definition

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Final
GDP per Capita Growth	-0.000757*** (-3.05)	-0.000839*** (-3.29)	-0.000669** (-2.25)	-0.000645** (-2.16)	-0.000731** (-1.98)	-0.000711* (-1.89)	-0.000968** (-2.33)	-0.000711*** (-2.58)
Net National Savings	-0.0000812 (-0.32)	-0.0000444 (-0.17)	0.00000756 (0.02)	0.0000297 (0.09)	0.000154 (0.40)	0.000143 (0.37)	0.0000708 (0.18)	
Inflation Rate	0.000454* (1.93)	0.000570** (2.32)	0.000517* (1.76)	0.000513* (1.76)	0.000454 (1.31)	0.000451 (1.30)	0.000677* (1.84)	0.000442* (1.68)
The Ratio of M2 to International Reserves		-0.00104*** (-2.88)	-0.000794** (-1.99)	-0.000810** (-2.00)	-0.00138** (-2.36)	-0.00139** (-2.37)	-0.00169*** (-2.70)	-0.00156*** (-3.53)
Deposit Interest Rate			0.000152 (0.30)	0.000192 (0.38)	-0.0000569 (-0.09)	-0.0000195 (-0.03)	0.000106 (0.16)	
Real Effective Exchange Rate				0.000566 (1.03)	0.000581 (0.87)	0.000573 (0.86)	0.000585** (2.83)	0.000810** (2.21)
Domestic Credit Provided by Banking Sector					-0.000615 (-1.22)	-0.000625 (-1.23)	-0.000742 (-1.43)	
Public and Publicly Guaranteed External Debt Stocks					-0.000266 (-0.35)	-0.000226 (-0.29)	-0.000146 (-0.18)	
Total Reserves (% of Total External Debt)					-0.000853 (-1.50)	-0.000864 (-1.51)	-0.00116* (-1.94)	-0.000593 (-1.40)
The Ratio of Foreign Direct Investment to GDP						0.000120 (0.27)	0.0000930 (0.20)	
Portfolio Equity Net Inflows							-0.000771 (-0.74)	
<i>N</i>	943	943	644	644	426	426	396	685
Log Likelihood	-132.0988	-127.63188	-90.981934	-90.440733	-62.512013	-62.474944	-55.721068	-99.201178
LR chi2	14.22	23.16	11.42	12.50	16.55	16.63	22.88	26.74
Prob > chi2	0.0026	0.0001	0.0437	0.0517	0.0562	0.0830	0.0184	0.0002

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Estimates are fixed effect panel estimation results

Using a nonparametric bootstrap, Stata provides a heteroscedasticity robust covariance

According to the estimation results, GDP per capita growth is an important indicator of a currency crisis when the crisis is defined with EMP Index. It is significant with a negative sign in all models. In other words, this variable keeps its significance even though it is considered with different variable sets. GDP per capita growth has a negative impact on the probability of a currency crisis. As expected, if GDP per capita growth rate increases the probability of a currency crisis decreases.

The inflation rate is significant in the first four models, but loses significance when debt profile measures (domestic credit to banking sector, public and publicly guaranteed external debt shocks and total reserves) are included into the model. This variable has a positive impact on the occurrence of a currency crisis meaning that increasing values of inflation rate increases the possibility of currency crisis as expected.

According to the empirical results, the ratio of M2 to international reserves is another important variable for the logit regressions that are constructed with EMP index based currency definitions. It is significant at 5% confidence level depending on the explanatory variables sets that it is tested with. As M2 to international reserves increases probability of a crisis decreases.

Real effective exchange rate yields significant results at 5% significance level only in some models and is not robust to model specifications. As it is expected increase in real effective exchange rate increases the probability of a crisis.

The variable total reserves (% of total external debt) reveals significant result in Model 7 with negative sign. Therefore, an increase on total reserves decreases the probability of crisis as expected. However, when total reserves (% of total external debt) is regressed with GDP per capita growth, the ratio of M2 to international reserves, inflation rate and real effective exchange rate in the final model, it does not show significant results anymore.

Furthermore, the variables net national savings, domestic credit provided by banking sector, public and publicly guaranteed external debt stocks, the ratio of foreign direct investment to GDP and portfolio equity net inflows are not significant indicators of a currency crisis when currency crisis is defined with EMP Index.

The final model is constructed with the significant variables. Out of these, the remaining significant variables are GDP per capita growth, the ratio of M2 to international reserves, inflation rate and real effective exchange rate are significant indicators of a currency crisis according to the model which is constructed with EMP index.

5. CONCLUSION

In this study, the same set of explanatory variables, econometric method (logistic regression), country set and time period (1970-2010) for both depreciation based crisis definition and EMP Index based crisis definition are used to be able to identify the impacts of crisis definitions on the significances of crisis indicators. The results have shown that, different definition methods identify different sets of variables as crisis indicators. While the GDP per capita, inflation, the ratio of M2 to international reserves, real effective exchange rate and domestic credit provided by banking sector (% of GDP) were significant in at least one of the regressions for the depreciation-based currency crisis definition; GDP per capita, inflation rate, the ratio of M2 to international reserves, real effective exchange rate and total reserves (% of total external debt) were significant in at least one of the regressions for the EMP index based currency crisis definition.

These findings are important in the EWS analysis as those significant variables are incorporated while forecasting the performances of the models and directly affect the prediction ability of the models.

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