Analysis of Currency Crises: Applying Dynamic Probit Model

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(Received on November 10, 2014)

1 Introduction

The severity and speed of the 2008 global financial crisis have rung the bell that makes economists and policy makers rekindle the interest studying currency crises to find out what drive them and how to mitigate the perverse crisis impact. Some of empirical studies are focused to renew the existing models with hopefully to able to predict occurrence of crises at an earlier stage more effectively.

In the background, the study analyzes the determinants of currency crises to identify a set of leading indicators and develops a dynamic probit model that expectedly produce better predictive power of currency crises than static models and other approaches.

Contrary to previous empirical studies, the paper applies maximum simulated likelyhood (MSL) estimation for dynamic probit model with autocorrelated errors. The approach exploits the full information of dataset, along both cross country and time dimension. It means the dynamics of crises can be apprehended by lagged binary crisis variables that representing past policy taken by a certain

country. The paper also takes on a challenge of arguing some definitions and the measurement of currency crisis to provide some comparison of empirical models.

2 Theoretical Models of Crises

This section reviews briefly the theoretical models on currency crises with the aim of providing some background on how to identify a set of leading indicators for analysis of currency crises.

2-1 First Generation Theoretical Models

The theoretical literature on currency crises has been developed following Krugman's seminal paper of 1979 that based on the work of Salant and Henderson (1978). In later years, Flood and Garber (1984), Connolly and Taylor (1984), Calvo (1987), and Edwards (1989) have extended and simplified the Krugman's work. These models evolved in response to crises in Latin American countries in 1970-80s, such as Mexico (1973-1982), Argentina (1978-1981), and Chile (1983). The main insight of the first generation models was that crises arose as result of bad policies in weak economic fundamentals and rational arbitrage of speculators, it was not relative to market malfunctioning. In the most case, there were inconsistencies between fixed exchange rate regime and chronic fiscal deficit that forced government pursuing expansionary monetary policies. As the result, foreign reserves run out and led to inflation in these countries. In that situation, speculators anticipated the government could not keep the exchange rate fixed under weakness in the economy like that. They started speculative attacks on currency and currency crises occurred eventually.

2-2 Second Generation Theoretical Models

The key characteristics of the first generation models failed to explain the speculative attacks on the European Monetary System (EMS) in 1992-93 that seemed

unrelated to the economic fundamentals.

After reunification, Germany implemented high interest rate policy to fight inflation in the early 1990s. At the same time, other European countries were plagued by economic stagnation, for example France and Great Britain were facing high unemployment and interest rates, but they could not follow expansionary monetary or fiscal policies with the reason they had to link their currencies to the Deutsuchemark through EMS. Moreover, right before the crisis, German interest rate was decreasing. However, the crisis erupted so abruptly and unexpectedly. How can it be explained? It raised a controversial theme that if the speculation is not determined solely by the economic fundamentals, what would other factors be considered of? In order to answer these questions, Obsfeld (1994, 96), Calvo (1995), Isard (1995), Sutherland (1995), Sachs, Tornell and Velasco (1996), Cole and Kehoe (1996), and Flood and Marison (1998) have developed a number of new models. The main explaining of these models was crises as consequence of self-fulfilling expectations in theoretical settings with multiple equilibria that were the most attention theories of the second generation models. It is not always like people thought as previously, "fundamentals" cause "market expectations". It means a weak macroeconomic condition makes people participate in bad consequences that lead to crises. However, converse phenomenon might also occur, "market expectations" make "fundamentals" change. It means market expectations might make fundamentals getting worsen even they are not bad as people thought. Ultimately, the worst consequence happens that is currency crisis. In fact, the causality of fundamentals and market expectations affect mutually, this circularity can lead to multiple equilibria. In the circular process, government plays a role of active agent who chooses the option that their costs are optimal in the view of government under the certain of economic environment. It means government weights the benefit and the cost of the exchange rate commitments, if necessary, they might devalue, revalue or even float the exchange rate in order

to minimum the costs of its policy. The reason makes government do like that because the government is not able to afford the prohibitive costs to maintain the fixed exchange rate. In the situation, the "fundamentals" that they consider about are not only "hard fundamentals" as usually thought like current account, interest rates variable and others, but also "soft fundamentals" such as the sentiment or heuristics of market participants that taken into account as important factors.[1)]

The disconnection between economic fundamentals and crisis timing of EMS crises made people think speculation in the different way. Speculation is motivated not only by economic fundamentals; it is also determined by the self-fulfilling mood of market. This provides a useful insight of the occurrence and precise timing of crises that is may be impossible to predict the timing of crises exactly solely on the basis of fundamentals. It is not necessary to tell that fundamentals plays a crucial role, because if it is not fragile or deteriorated, it would not make currency ripe for an attack.

2-3 Third Generation Theoretical Models

Difference from the aspects of second generation, the outburst of the Asian crisis in 1997-98 has prompted a number of economists to call for a third generation models of currency crises.

The Asian crisis seems to have differed from crises described in the previous models. It is harder to characterize features of the crisis simply based on existing models. Generally new models are therefore developed by putting the analytical focus on distortions in financial markets, banking systems, and the contagion of crises across countries. Some features of the third generation models are near to the second one that speculative attacks of the third generation also take into account multiple equilibria, but now the interaction between governments with

1) See more details at Isard (1995).

speculators is shifted to financial intermediates with speculators. "Financial Liberalization", "Over Borrowing Syndrome", "Implicit or Explicit Government Guarantees", "Moral Hazard", and "Bank Run" are added to the model that considered as the important features to explain currency crises.

3 Identifying a Set of Explanatory Variables

As specified in the previous section of theoretical models of crises as well as other empirical studies[2] were validated, the objective of this section is to make the choice of the set of leading variables. These explanatory variables are identified here including all of the concept such as "Speculative Attack", "Self-Fulfilling", "Multiple Equilibria", "Distortion of Financial and Banking System", and "Contagion of Crisis" that are expected to reflect all main potential determinants to force countries' vulnerabilities to crisis.

The first variable is the real growth rate of GDP that is crucial variable because government has tended to make its currency devalue when economic growth is low with two reasons. First, low growth economy makes government difficult to keep its economy to sustainable as well as it has fewer resources to defend itself against an attack. Second, government devalues its currency to gain competitiveness and boost the economy to growth again. The second variable is the current account as a percentage of GDP that is also a key variable for analysis of currency crisis. The deterioration of this variable is considered as one of determinant that makes a crisis to occur. The third variable is the ratio of short term debt to foreign reserves. The higher short term debt, the more vulnerability of the economy is. The lower level of foreign reserves, the easier for speculators attack their currencies. The fourth variable is government budget as a fraction of GDP that could provide a signal based on the first generation theoretical model.

2) See more details at Frankel and Rose (1996), Kaminsky and Reinhart (1999).

The fifth variable is the increase of the credit to private sector that is designed to capture weakness in financial system. The sixth variable is the extent of the real of exchange rate over appreciation that defined as deviation of real effective exchange rate from a linear trend. The seventh variable is the unemployment rate that is considered as political costs that might trigger a crisis. The eighth variable is the short term capital inflows. If a country has a large amount of short term capital inflows denominated in foreign currencies, the suddenly stop or reversal of capital flows will make a sharp devaluation. The ninth variable is the correlation of equity returns between the countries that considered as herding contagion. The real interest rate and inflation are also added to the model as the tenth and eleventh variables.

4 Definition of Currency Crisis

This section discusses definitions of currency crisis and its measurement which is one of the most debatable issues while dealing with analyzing currency crisis.

A currency crisis is often defined as a sharp depreciation of the nominal exchange rate. However, in the situation, a country found with a strong rise in interest rates or/and sudden fall in foreign reserves is also considered as a country under high pressure on speculative attacks of exchange rate. Both cases above are considered as successful and unsuccessful speculative attack respectively.

In the case of successful speculative attack, the devaluation rate has to be large enough. To measure this, the following measurement can be acceptable.

$$\delta^{qtr}_{nom_{it}} > 15\%$$

Where $\delta^{qtr}_{nom_{it}}$ is one quarter change rate of the nominal exchange rate in the economy i at the time t. The threshold value of 15 percent is reasonable in somewhat, when comparing with other studies and in the sensitivity analysis.

However, it is also necessary to think about the depreciation of nominal

exchange rate in the country with high inflation that is often correspondingly with sharp expected rates of depreciation. In order capture a currency crisis in this case, the following measurement can be used.[3)]

$$\begin{cases} \delta_{rer_{it}} > 2.54\sigma_i^{\delta_{rer}} \\ \delta_{rer_{it}} > 5\% \end{cases}$$

Where $\delta_{rer_{it}}$ [4)] is the two month changes of real exchange rate in the economy i at time t. $\sigma_i^{\delta_{rer}}$ is the standard deviation of two month changes in real exchange rate in the economy i.

In the case of unsuccessful speculative attack, currency crises are defined as a large change in exchange market pressure index (EMPI). The intuition behind here is if there is an attack on the currency severely, government may raise interest rates and/or deplete foreign reserves to defend exchange rate. Referring to this definition, the EMPI is constructed as following.

First, EMPI is calculated as a weighted average of the change in real exchange rate, in foreign reserves and in real interest rates as below:

$$EMPI_{it} = \omega_{rer}\left(\frac{rer_{it} - rer_{it-1}}{rer_{it-1}}\right) + \omega_r\left(r_{it} - r_{it-1}\right) - \omega_{resv}\left(\frac{resv_{it} - resv_{it-1}}{resv_{it-1}}\right)$$

Where rer_{it} is the real exchange rate, r_{it} is the real interest rate (short term rate), $resv_{it}$ is the level of foreign reserves in the economy i at the time t, ω_{rer}, ω_r, ω_{resv} are the weights each, respectively.

Second, transform EMPI into a binary variable using cut-off level 1.5 standard deviation.

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3) The similar thingking also found in Eichengreen, Rose and Wyplosz (1995, 1996), Goldfajn and Valdés (1997), and Kaminsky, Lizondo and Reinhart (1998) to define a crisis.

4) Capture changes in the real exchange rate that lie in the upper 0.5% of the distribution.

$$y_{it} = \begin{cases} 1 & if \quad EMPI_{it} > \mu_{EMPI_i} + 1.5\sigma_{EMPI_i} \\ 0 & if \quad otherwise \end{cases}$$

Where μ_{EMPI_i}, σ_{EMPI_i} is the average and standard deviation of EMPI in the economy i respectively.

5 Estimation Methodology: Dynamic Probit Model

The study analyzes the determinants of currency crises to identify a set of leading indicators and develops a dynamic probit model that links the binary currency crisis index to the set explanatory variables.

The probit approach of studying currency crises is not new, but the methodology applied here that is different from previous empirical studies treats currency crises as a dynamic events. Why should they be treated like that? The reason is if the countries did experience currency crisis that leads them behave differently from other countries where have no such experience. In this situation, there may be something changed in its economy or some new constrains are set up that is often called as *true state dependence.* In order to capture this effect, a lagged dependent variable is added in the probit model.

Specifically, the following equation used to estimate the effects of the economic fundamentals, financial and other variables[5] on the probability of currency crises.

$$y_{it}^{*} = \gamma y_{it-1} + \mathbf{x}_{it}\beta + \alpha_i + \varepsilon_{it} \qquad (1)$$

$$(\ i = 1,...,N;\ t = 2,...,T\ )$$

Where y_{it}^{*} is the latent variable to measure the probability of an occurrence of currency crises in economy i at the time t. $\mathbf{x}_{it}$ is a vector of the observation of

5) More details see section 3.

variables of economy i at the time t to explain the determinant of currency crises. β is a vector of corresponding estimated coefficients, and γ is expression of state dependence. ε_{it} is error term to the currency crises index. Furthermore, assuming that ε is serially independent of x and generated by random from $N(0,\sigma_\varepsilon^2)$, individual specific time invariant α_i terms.

The individual specific random effects (RE) specification adopted implies equicorrelation between the v_{it} in any two different periods.

$$\lambda = corr(v_{it}, v_{is}) = \frac{\sigma_\alpha^2}{\sigma_\alpha^2 + \sigma_\varepsilon^2}$$

$$(\ t, s = 2,...,T \ ; \mathrm{t} \neq \mathrm{s} \ )$$

The standard uncorrelated RE model also assumes α_i independent identically distributed with $N(0,\sigma_\alpha^2)$ with x_{it} .

For y_{it}^* is not observable, the following y_{it} (observed) which is called index function of currency crisis events in economy i at time t, takes on the value one if the event occurs and zero otherwise.

$$y_{it} = \begin{cases} 1 & if \ \ y_{it}^* \geq 0 \\ 0 & otherwise \end{cases}$$

The paper also takes into account the fact that countries' differences may be correlated over time. If the structure of the errors are not treated properly may cause a conditional relationship between future and past experience that is termed spurious state dependence.[6] In order to avoid this problem, assuming that the error term ε_{it} in the structure is autocorrelated. The estimation of the dynamic probit model requires T-dimensional integrals of normal densities. Here applies the maximum simulated likelihood (MSL) estimator that developed by Gourie'

6) See more details at Hyslop (1999).

roux and Monfont (1996), and Cameron and Trivedi (2005) based on the Geweke-Hajivassiliou-Keane (GHK) algorithm (Keane 1994). The ε_{it} follows a first-order autogressive (AR1) process. The variance-covariance matrix, Ω, of $v_i = (v_{i1},...,v_{iT})'$, will now be function of λ, θ, and one more parameter. The error vector can be written as $v_i = C\eta_i$, with $\eta_i \sim N(0,I)$ and C the lower triangular Cholesky decomposition of Ω ($CC' = \Omega$).

Using the Cholesky decomposition, (1) can be written as

$$y_{it}^{*} = \gamma y_{it-1} + \mathbf{x}_{it}\beta + \sum_{j=1}^{t} c_{tj}\eta_{ij} \qquad (2)$$

$$(t \geq 2)$$

$$y_{it}^{*} = \mathbf{z}_{i1}\pi + \eta_i \qquad (3)$$

$$(t = 1;\ \mathrm{i}=1,...,\mathrm{N})$$

Where $\mathbf{z}_{i1}$ is a vector of exogenous instruments (and includes $\mathbf{x}_{i1}$) and η_i is correlated with α_i , but uncorrelated with ε_{it} for $t \geq 2$.[7)]

From (2) and (3) and the assumption given, the probability for observed y can be derived from

$$\Pr_i = \Phi\left\{(y_{i1}-1)\frac{\mathbf{z}_{i1}\pi}{c_{11}}\right\} \times \int_{L_{i1}}^{U_{i1}} \Phi\left\{(y_{i2}-1)\frac{\gamma y_{i1} + \mathbf{x}_{i2}\beta + c_{21}\eta_{i1}}{c_{22}}\right\}\phi(\eta_{i1})d\eta_{i1}$$

$$\times \int_{L_{i1}}^{U_{i1}}\int_{L_{i2}}^{U_{i2}} \Phi\left\{(y_{i3}-1)\frac{\gamma y_{i2} + \mathbf{x}_{i3}\beta + c_{31}\eta_{i1} + c_{32}\eta_{i2}}{c_{33}}\right\}\phi(\eta_{i1})d\eta_{i1}\phi(\eta_{i2})d\eta_{i2}$$

$$\times ...$$

Where $(\mathrm{L}_{it}, U_{it}) = (-\frac{\gamma y_{it-1} + \mathbf{x}_{it}\beta}{c_{tt}}, \infty)$ if $y_{it} = 1$ or $(-\infty, -\frac{\gamma y_{it-1} + \mathbf{x}_{it}\beta}{c_{tt}})$ if $y_{it} = 0$.

For a sequence of length T, this probability will be the product of T such terms.

7) See more details at Heckman (1981).

6 Conclusion

The study gives the framework to analyze the currency crisis by employing a dynamic probit model with the set of leading indicators. The eminent of the approach is able to exploit the full information of dataset, along both cross country and time dimension. It also provides a comprehensive discussion of some definitions and measurements of currency crises to make it comparable with others.

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