Chinese Currency Unit and Financial Crisis: Evidence from Early Warning Systems

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Abstract

This study deals with currency crises and the Chinese currency unification (CCU). It used an ordered probit model in comparing the accuracy of three different early warning systems and analyzing the key factors. The results showed that real exchange rate and consumer price index (CPI) changes are the most significant variables. Real interest rates significantly influence the probability of currency crises, revealing a greater marginal effect in the CCU regime. Hence, CCU members should maintain higher real interest rates to attract capital inflow and to fend off speculative attacks. Further, to alleviate the impacts of crises on the CCU regime, policy makers should stimulate the stock market to avoid overheating and to stabilize GDP growth. The predictive accuracy of the CCU regime is higher than specific exchange rates. Reliability thresholds also revealed that the CCU regime is a feasible economic system capable of preventing currency crises.

Keywords: Regional Integration, Currency Crisis, Early Warning System, Chinese Currency Unit

I. Introduction

Over the past decades, the economic studies have been analyzed the link between countries' economic characteristics and their exchange-rate regime (Mundell, 1961; McKinnon, 1963). Notable contributions focusing on Asian countries are Dutta (2000), Swofford (2008), Bayoumi and Eichengreen (1994), Kawai (2008), Shirono (2008) among others. None of them, however, specifically assess the stabilizing effects- such as making crises more predictable- of currency unification. This paper could potentially provide original insights on this point.

The 1997 Asian currency crisis brought serious repercussions to Asian countries. By contagion, its effects spilled over to neighboring states. To check the threshold of currency crises in the context of an Asian Currency Unit (ACU), Chen and Hsiao (2006) used ordered probit and logit models with random effect. They claimed that the formation of an ACU could effectively reduce the probability of another currency crisis. On the other hand, Li (2006) found that stock index and specific exchange rate are significant variables in the establishment of an ACU. Further, he claimed that real interest rates play a pivotal role in the occurrence of currency and bank crises or the so-called twin crises. He concluded that based on marginal effect, real interest rates highly affect bank and currency crises in Taiwan. Chen and Fang (2008) argued that the most important factors influencing the contagion effect are

macroeconomic similarities. However, the economic, political, and cultural differences among ASEAN+3 members are still difficult to overcome. Hence, the adoption of an ACU is currently not appropriate (Bayoumi and Eichengreen, 1994; Mundell, 2007).[1]

In contrast to the complex situation within ASEAN+3, Mainland China, Taiwan, and Hong Kong had relatively closer relationships on the radical and cultural sides. The relationship between Mainland China and Taiwan has now become gentler than what it once was. Important trade partnership will continue to stay strong. To consider the feasibility of an ACU, Lu (2004) simulated a Chinese Currency Unit (CCU) and analyzed its relationship with macroeconomic variables, suggesting that money supply and CPI are significant in the adoption of CCU. Cheng (2008) also supported that M2 growth is a major factor affecting the possible adoption of CCU.

In reducing the impact of financial crises, the early warning system (EWS) has been proven reliable. Depending on various economic models on currency crises, different formulations and variables are involved. Each model is established from the contributions of its predecessors. For instance, Eichengreen et al. (1996) developed a weighted index, the Eichengreen-Rose-Wyplosz (ERW) method, to predict financial crises. This model consists of weighted relative changes of exchange rate, international reserves, and interest rates. The concept behind this method is similar with first-generation currency crisis theories. Kaminsky et al. (1998) followed the ERW model but excluded interest rates because they are controlled by central banks (Lestano, Jacobs, and Kuper, 2003). Within the extensive literature on EWS, comparatively little research has focused on the relationship between CCU and EWS. Hence, by simulating CCU, this research seeks to examine the performance of EWS and to search for a suitable method for predicting the occurrence of financial crises.

This paper utilizes data on export volume, net reserves, and GDP per capita of Mainland China, Taiwan, and Hong Kong. These factors were accorded with varied weights to simulate the central rate of CCU members in the past decade, based on special drawing rights (SDR) and the euro. This study employed three computing methods to construct CCU and its thresholds. The methods were compared to determine the most suitable one in predicting the occurrence of financial crises. Further, this work adopts the ordered probit model to analyze macroeconomic variables, such as export growth, GDP per capita, real interest rate, and the ratio of M2 to foreign exchange reserves, to search for factors affecting the probability of a financial crisis under CCU. The results show that real exchange rate and CPI changes are important in preventing currency crises. Meanwhile, real interest rate, stock index growth,

[1] Source: Udndata.com, 2007; Economic Daily (2007/9/23), "Mundell: Asian nations should build Fixed Exchange Rate Region."

and GDP growth play pivotal roles in controlling the pressures of currency crisis, thus saving CCU members from its menace. By examining the reliability of EWS and its predictive accuracy, a CCU regime could lessen the probability of speculative attacks better than the specific exchange rates.

II. Literature review

The favorable establishment of the European Currency Unit (ECU) provides an acceptable reference to Asian countries. The possibility of constituting an ACU is gradually becoming feasible (Mundell, 2003). It may bring tremendous economic benefits and vitality to the global society. Based on Mundell's prediction, Asia will equally compete with the Euro zone and will severely threaten the US zone in terms of economic capability by 2020.

In light of studies on Asian exchange rates, Raj and Mbodja (1996) concluded that the Japanese yen influences Asian currencies more than the US dollar does. More importantly, the Asian economic and financial integration is tighter than before. In addition, Tzeng (1999) estimated the stability of the euro and posited the possible establishment of an ACU. He claimed that the integration of two currencies is feasible when both countries exhibit relatively high exchange rate movements. The creation of the European Union that established the euro may provide a suitable framework in creating an ACU. By setting up the common currencies to establish an optimal currency zone, Tzeng strongly recommended that an Asian Union may include Taiwan, Indonesia, Korea, Malaysia, the Philippines, and Thailand because of their similar economic scales.

In comparing regional currency agreements among ASEAN, Mercosur (Southern Common Market), and North American Free Trade Agreement (NAFTA), Bayoumi and Mauro (2001) found that the economic scale and political conditions of ASEAN (The Association of Southeast Asian Nations) nations are considerably different from other geographic groupings. To some degree, they suggested that the successful currency integration experience of the EU could provide an example for integrating Asian currencies and for establishing a similar organization.

To differentiate the probability of the occurrence of a currency crisis under an ACU (and in each member country) and in the US, Chen and Hsiao (2006) adopted ordered probit and ordered logit models to examine the different weight thresholds of currency crises. These models were built on speculative pressure and exchange rate pressure indices. Their findings conclusively proved that these models excellently anticipated the occurrence of an Asian currency crisis, which could be efficiently alleviated by establishing a stable ACU. In terms of its predictive capability, the estimated threshold comprising CPI and real interest

rates may be more accurate than those of each country's currency against the US dollar. In order to reduce the occurrence of currency crises and to prevent currency meltdowns, governments could control these two variables.

In considering the relationship between an ACU and the twin crises, Li (2006) built foreign exchange pressure indices to estimate the relationship between macroeconomic factors and the twin crises by considering the weakness indices of banks. The findings indicated that regardless of specific exchange rates and central exchange rate systems, stock indices play an important role in bank crises. Moreover, real interest rates and bank deposits considerably influence the twin crises. With regard to the marginal effect, real interest rates largely influence bank and currency crises in Taiwan. Regarding the financial crisis in Asia, Chen and Fang (2008) found that financial linkages and macroeconomic similarities are the primary reasons behind the contagion effect.

After the shock of the 1997 Asian financial crisis, majority of economists and professionals reconsidered the possibility of establishing an ACU and of intensifying integration in economic activities. However, the cultural, political, and economic differences existing among Asian countries make regional integration more difficult and challenging.

Cheng (2008) pointed out that the creation of a Chinese Currency Unit (CCU) than an ACU is more realistic, considering that economic integration necessitates the utilization of sufficient foreign reserves. To study the stability of CCU, Chen (2004) simulated the currency based on the weights of GDP per capita, export, and reserves of China, Taiwan, and Hong Kong from 1995 to 2003. Results of generalized autoregressive conditional-heteroskedasticity (GARCH) analysis show that CCU will be stable and short-term interest rates and CPI are the most important macroeconomic factors for Mainland China. Further, Taiwan and Hong Kong should pay attention to the stability of money supply and CPI.

Lu (2004) showed that CCU will be influenced by CPI and money supply of Taiwan, while the terms of trade of Taiwan will greatly affect CCU. In addition, Lu indicated that money supply, CPI, custom duties, and terms of trade will easily be influenced by CCU, and conversely, CCU will be deeply influenced by money supply, CPI, and custom duties.

Cheng (2008) reported that CCU would be greatly affected by the industrial productive index, GDP, stock price index, and net foreign reserves. The results of ARIMAX (autoregressive integrated moving average with exogenous variables)-GARCH revealed that industry productive index, money supply growth rate, and trade factors are significant, and

the length of their effects is long enough to influence CCU.

A currency crisis, caused by a speculative attack for the devaluation of the currency, can severely damage a country. It may not only force the authorities to defend the currency by using large volumes of international reserves or by sharply raising the interest rates, but also bring the collapse of government credits and the local currency, causing the flight of foreign investors. (Chiodo and Owyang, 2002; Krugman, 1979)

After a series of widespread financial crises in the 1990s, economists began to investigate the contagion effect. Eichengreen et al. (1996) defined the contagion effect as a case of crisis elsewhere that increases the probability of a crisis at home, even under sound fundamentals. Gerlach and Smets (1995) and Glick and Andrew (1999) found that speculative attacks have contagious effects when a currency is devaluating. They lead to the enforcement of competition among trade partners, and the fragility of currency passes to other countries.

Currency crises pose serious risks. Economists have attempted to determine the factors causing currency crises. Some attempted to build EWS to forecast the occurrence of crises. Kaminsky et al. (1998) developed the signal approach model or the so-called Kaminsky-Lizondo-Reinhart (KLR) model, and they tested the predictive capability of this method in Asia. Their findings indicated that real exchange rates, exports, stock prices, M2/foreign reserves, and output are significant in forecasting currency crises. Accordingly, an annual percentage change of more that 10% in an indicator signals a crisis. To minimize the noise-to-signal ratio, an optimal set of country-specific thresholds can be used.

Edison (2003) modified the signal approach and created the Exchange Market Pressure Index (EMPI) as a mixed signal. EMPI is composed of the nominal exchange rate and the percentage change in foreign reserves. Edison showed that this benchmark model is better than the traditional KLR model. Furthermore, the results revealed that the empirical coefficients of reserves, exports, the real exchange rates, M2/reserves, and imports have at least one signal prior to a crisis. When a currency crisis occurs, reserves, the stock index, and real interest rates will sharply drop down.

In analyzing contagion in a currency crisis, Caramazza et al. (2004) indicated that the emergence of crisis is associated with financial linkages, especially a common creditor. They found that this variable is the most robust, providing the largest contribution to the probability of a crisis. Moreover, the indicators of financial fragility, such as reserves adequacy, and output growth play important roles in predicting the probability of crises.

III. Methodology

III.1. Measuring the Exchange Market Pressure Index (EMP)

To identify a speculative attack, economists developed exchange market pressure indices (EMP). Three methods were developed by Eichengreen et al. (1996), Kaminsky et al. (1998), and Edison (2003) to evaluate the level of a currency crisis. Accordingly, changes in interest rates, exchange rates, and foreign reserves are significantly associated with a currency crisis.

These three models follow the same logic in predicting the occurrence of a speculative attack. The higher the devaluation of the exchange rate, the greater is the outflow of foreign reserves; hence, higher interest rates are adopted. This would push the EMP score higher. To further differentiate the probability of financial crises occurrence, crisis at three levels was defined, which was represented as Crisis = 0, 1, and 2. This definition is based on EMP scores and sample standard deviations.

Eichengreen et al. (1995) developed a method to measure currency pressure and to analyze currency crises. To capture successful and unsuccessful speculative attacks, the so-called ERW model was conceived. The index is relative to a reference country and its time-independent thresholds:

$$EMP_{i,t} = \alpha\Delta e_{i,t} + b\Delta\left(i_{i,t} - i_t^*\right) - c\left(\Delta r_{i,t} - \Delta r_t^*\right), \quad (1)$$

$Crisis = 2$ if $\text{EMP}_t > 2.0\sigma_{EMP} + u_{EMP}$,
$Crisis = 1$ if $\text{EMP}_t > 1.5\sigma_{EMP} + u_{EMP}$,
$Crisis = 0$ if otherwise,

where $\Delta e_{i,t}$ denotes the change in exchange rate of country *i* at time $i_{i,t}$, and i_t^* denotes country *i*'s interest rate and the interest rate of the reference country. $\Delta\left(i_{i,t} - i_t^*\right)$ is the change in interest rate difference between $i_{i,t}$ and i_t^*. $r_{i,t}$ is the ratio of foreign reserves of country *i*, and r_t^* is the same ratio for the reference country. The difference in foreign reserve change between country *i* and the reference country is $\left(\Delta r_{i,t} - \Delta r_t^*\right)$. *a*, *b*, and *c* represent weights.[2] σ_{EMP} and u_{EMP} symbolize the sample standard deviation and the sample mean of EMP. For instance, when the EMP score in the ERW model is 2 standard

[2] Following Eichengreen et al. (1996), Tudela (2004), and Chen and Hisao (2004), the summation of a, b, and c is 1. To build different threshold levels, they utilized different combinations of a, b, and c with 0.2, 0.3, and 0.5 as weights, respectively.

deviations greater than the mean, then the economic system is at a higher risk of a financial crisis. Following the formulation, this crisis is denoted as Crisis = 2. When the EMP score in the ERW model is 1.5 standard deviations greater than the mean, then the economic system may suffer a financial crisis because of its financial weaknesses. This is denoted as Crisis = 1. Following the same logic, Crisis = 0 shows a low probability of occurrence of a financial crisis.

Kaminsky et al. (1998) and Kaminsky and Reinhart (1999) closely followed the concept of Eichengreen et al. (1996). However, they excluded interest rate differentials from their indices because interest rates are controlled by central banks. They formed the well-known KLR method, which is defined as follows:

$$EMP_{i,t} = \frac{\Delta e_{i,t}}{e_{i,t}} - \frac{\sigma_e}{\sigma_r}\frac{\Delta r_{i,t}}{r_{i,t}} + \frac{\sigma_e}{\sigma_i}\Delta i_{i,t}, \quad (2)$$

$$Crisis = 2 \text{ if } \mathrm{EMP_t} > 1.5\sigma_{EMP} + u_{EMP},$$
$$Crisis = 1 \text{ if } \mathrm{EMP_t} > 1.0\sigma_{EMP} + u_{EMP},$$
$$Crisis = 0 \text{ if otherwise,}$$

where $EMP_{i,t}$ is the exchange rate market pressure index for country i at period t. $e_{i,t}$, $r_{i,t}$, and $i_{i,t}$ are the units of country i 's currency per US dollars, gross foreign reserves, and nominal interest rate, respectively. The relative change in exchange rate and foreign reserves are defined as $\frac{\Delta e_{i,t}}{e_{i,t}}$ and $\frac{\Delta r_{i,t}}{r_{i,t}}$. $\frac{\sigma_e}{\sigma_r}$ and $\frac{\sigma_e}{\sigma_i}$ are the relative change in standard deviations in both exchange rates and reserves, and the relative change in standard deviations in both exchange rates and interest rates, respectively. $\Delta i_{i,t}$ defines the change in interest rate.

Edison (2003) measured EMP as

$$EMP_{i,t} = \Delta e_{i,t} - \alpha_{i,t} \cdot \Delta r_{i,t}, \quad (3)$$

$$Crisis = 2 \text{ if } \mathrm{EMP_t} > 2.5\sigma_{EMP} + u_{EMP},$$
$$Crisis = 1 \text{ if } \mathrm{EMP_t} > 2.0\sigma_{EMP} + u_{EMP},$$
$$Crisis = 0 \text{ if otherwise,}$$

where $e_{i,t}$ denotes the foreign currency of country i to US dollars at time t, $r_{i,t}$ denotes foreign reserves, and $\alpha_{i,t}$ is the relative change in standard deviation of both exchange rates and reserves.

III.2 Ordered Probit Model

This paper adopted the ordered probit model to examine what variables could influence financial crises. The ordered probit model is specified as

$$y_{it}^{*} = \alpha + \beta' x_{it} + \varepsilon_{it} \text{ ,} \tag{4}$$

where y_{it}^{*} cannot be observed, and what could be observed is

$$\begin{aligned} y_{it} = 0 \text{ ,} \quad & \text{if} \quad y^{*} \le \mu_0, \\ 1 \text{ ,} \quad & \text{if} \quad \mu_0 < y^{*} \le \mu_1, \\ 2 \text{ ,} \quad & \text{if} \quad \mu_1 < y^{*} \le u_2, \\ & \text{……..} \\ M, \quad & \text{if} \quad y^{*} \ge \mu_M, \end{aligned} \tag{5}$$

$$Var[\varepsilon_{it} + \alpha_i] = Var[v_{it}] = \sigma_{\varepsilon}^2 + \sigma_{\alpha}^2,$$

$$Cov[v_{it}, v_{is}] = \sigma_{\alpha}^2,$$

$$Corr[v_{it}, v_{is}] = \rho = \frac{\sigma_{\alpha}^2}{\sigma_{\varepsilon}^2 + \sigma_{\alpha}^2}.$$

Note that u_s are unknown parameters and are unobservable measures of crisis levels, but they could be estimated by β. $y_{i,t}$ refers to the observed variables. α_i denotes a constant, and ε_{it} represents the residual with normal distribution, N $(0, \sigma^2)$. (Borooah, 2001). On the basis of likelihood function, y_{it} could be characterized as

$$\Pr ob(y_{it} = 0 \mid x_{it}, \beta, u) = \Phi(u_0 - \beta' x_{it}), \tag{6}$$

$$\Pr ob(y_{it} = 1 \mid x_{it}, \beta, u) = \Phi(u_1 - \beta' x_{it}) - \Phi(u_0 - \beta' x_{it}),$$

$$\Pr ob(y_{it} = 2 \mid x_{it}, \beta, u) = \Phi(u_2 - \beta' x_{it}) - \Phi(u_1 - \beta' x_{it}),$$

$$\Pr ob(y_{it} = M \mid x_{it}, \beta, u) = 1 - \Phi(u_{M-1} - \beta' x_{it}),$$

where Φ is the standard normal density. For all probabilities to be positive, we must have $0 < u_1 < u_2 < ..... < u_M$.

Considering the dependent and independent variables, the model can be rewritten as

$$\begin{aligned} \text{Crisislevel}_{it}^{*} = {} & \alpha_i + \beta_1 \cdot REEX_{it} + \beta_2 \cdot REINT_{it} + \beta_3 \cdot CAGDP_{it} + \beta_4 \cdot CPICH_{it} \\ & + \beta_5 \cdot STOCGR_{it} + \beta_6 \cdot GDPGR_{it} + \beta_7 \cdot M2FR_{it} + \beta_8 \cdot EXGR_{it} + \varepsilon_{it}. \end{aligned} \tag{7}$$

where REEX = real exchange rate,
REINT = real interest rate,
CAGDP = current account to GDP,
CPICH = CPI change,
STOCGR = stock index growth,
GDPGR = GDP growth,
M2FR = M2 to foreign reserves,
EXGR = export growth.

III.3. Marginal Effect

The marginal effect can be obtained by an ordered probit model using the different thresholds of each variable. Suppose there are three categories. The responding extent of the marginal effects from every independent variable could be described as follows (Greene, 2002):

$$\frac{\partial \Pr ob(y_{it}=0)}{\partial x_{it}} = -\Phi'\left(u_0 - \beta' x_{it}\right)\cdot \beta \qquad (8)$$

$$\frac{\partial \Pr ob(y_{it}=1)}{\partial x_{it}} = \left[\Phi'\left(u_0 - \beta' x_{it}\right) - \Phi'\left(u_1 - \beta' x_{it}\right)\right]\cdot \beta \ ,$$

$$\frac{\partial \Pr ob(y_{it}=2)}{\partial x_{it}} = \Phi'\left(u_2 - \beta' x_{it}\right)\cdot \beta \ ,$$

Increasing one of the x's while holding β and μ as constant is equivalent to shifting the distribution slightly to the right. Assuming that β is positive, $Prob\left(Y_{it}=0 \mid x_{it},\beta,u\right)$ will decline. This means that $Prob\left(Y_{it}=0 \mid x_{it},\beta,u\right)$ has the opposite sign of β. On the contrary, $Prob\left(Y_{it}=2 \mid x_{it},\beta,u\right)$ has the same sign of β because β is positive, and $Prob\left(Y_{it}=2 \mid x_{it},\beta,u\right)$ is increased after a right shift. Greene (1993) indicated that the events in the middle cell, $Prob\left(Y_{it}=1 \mid x_{it},\beta,u\right)$, are ambiguous.

III.4. Variable description

Based on the ECU composing system, Chen (2001) constructed an ECU calculation by referencing three weighted macroeconomic factors: GDP per capita, net reserve, and export volume. Chen's sampling data included 10 Asian currencies, namely, of Taiwan, Hong Kong, Japan, South Korea, Malaysia, Thailand, the Philippines, Indonesia, Singapore, and Mainland China. Different from the Special Drawing Right (SDR) and ECU, previous studies adapted to the intensely changing environment of Asian countries, adjusting the base weight of the proposed ACU every 3 years from March 1992 to March 2007. In the same vein, the proposed Chinese currency unit (CCU) also employed the same calculation and base time. The formulation was earlier defined as

$$CCU = \left(\frac{\text{each country's export volume}}{\text{sum of each country's export volume}} + \frac{\text{each country's net reserve}}{\text{sum of each coutnry's net reserve}} + \frac{\text{each country's GDP per capita}}{\text{sum of each country's GDP per capita}} \right) \times \text{exchange rate against US dollar} \times \text{special drwaing rights.} \quad (9)$$

The detailed simulation steps are as follows:

1. Gathering net reserve, export volume, and GDP per capita for the base periods (i.e., March 1992, March 1995, March 1998, March 2001, March 2004, and March 2007) from three currency areas.
2. Computing the base weights for the five base periods.
3. Calculating euro or SDR against US dollars.
4. Computing each area's weight and dividing the weights by the base weight.
5. Combining 2, 3, and 4 and the exchange rate of each area to obtain three area weights against CCU and generating a CCU trend.

By referring to the Maastricht Treaty framework and the Preferential Tariff Agreement (PTA) formed during the 4th ASEAN summit in January 1992, this research defined the quarterly data of real exchange rate, real interest rate, current account to GDP, CPI change, stock index growth, GDP growth, M2 to foreign reserves, and export growth and the sampling period from March 2, 1992 to December 30, 2008. As mentioned in the CCU calculation, the weights for three regions were adjusted against CCU every three years, and March 1992 was set as the base time. All data were mainly from the Advanced Retrieval Econometric Modeling System (AREMOS) database and the Taiwan Economic Journal (TEJ). SDR data were from the International Finance Yearbook.

To examine the relationship between CCU and EWS, this paper included the following independent variables:

1. Real interest rate

Real interest rate can be used to represent financial liberalization. The liberalization process tends to result in high real interest rates, signaling a liquidity crunch or fending off a speculative attack. Edison (2003) and Flood and Marion (2000) revealed that overvaluated real interest rates induce crises. Kaminsky and Reinhart (1998) showed that real interest rates were highly volatile prior to the East Asian currency crisis.

2. Real exchange rate

When a currency crisis occurs, the domestic CPI will sharply increase, resulting in real

exchange rate devaluation. Edison (2003) and Flood and Marion (2000) indicated that the devaluation of real exchange rates will induce a currency crisis. The real exchange can be defined as follows:

$$Real\ exchange\ rate = exchange\ rate \times \frac{foreign\ \text{CPI in foreign currency}}{\text{domestic CPI in domestic currency}} = e \times \frac{P_f}{P_d}.$$

Edison (2000) also argued that real exchange rates could be seen as a prior indicator of a currency crisis.

3. Ratio of current account to GDP

Eichengreen et al. (1995) showed that the ratio of current account to GDP is negatively correlated with currency crises. Frankel and Rose (1996) indicated that the ratio of the current account to GDP could raise the predictive value of crisis forecasts.

4. CPI change

Changes in CPI may sufficiently represent macroeconomic mismanagement, which is likely to be associated with high nominal interest rates that adversely affect the economy and the banking system. Chen (2001) indicated that inflation rate is a crucial indicator in the stability of a future ACU. Chiodo and Owyang (2002) argued that after a currency crisis, inflation rates would sharply decrease.

5. Stock index growth

Kaminsky et al. (1998) adopted stock index as a leading economic indicator and as an important reference for foreign investors. It reflects an economic boom or depression in a country. For instance, banks are willing to provide much larger loans to well-performing companies by usually presenting a good stock price. This tends to result in slavishness, especially in a booming economy. A banking crisis usually occurs when stock prices decline in advance (Kaminsky and Reinhart, 1999). The author hypothesized that a decline in stock price is associated with an increase in the likelihood of a banking crisis.

6. GDP growth

The deterioration of domestic economic activities caused by the decline in GDP growth is expected to increase the likelihood of a banking crisis. Hence, GDP growth could be seen as an indicator predicting the occurrence of a currency crisis. Glick and Rose (1998) indicated that the GDP is strongly related to currency crises.

7. Ratio of M2 to foreign exchange reserves

The liabilities of the banking system are backed by foreign currency reserves. This ratio captures the capability of the central bank to meet individuals' demands of converting their

domestic currency into foreign currency during the event of a currency crisis. By using the similar set of currency crisis indicators, Berg and Pattillo (1999) and Edison (2003) captured external shocks. All studies showed that the ratio of M2 to foreign reserves is the most important indicator predicting currency crises.

8. Export growth

A declining export growth may be caused by an overvalued domestic currency, reflecting the loss of competitiveness in the international market. Hence, export growth is a sound measure of currency overvaluation. On the other hand, the decline in export growth caused by reasons unrelated to the exchange rate may result in devaluation pressure. The decreasing export growth can be a leading indicator to examine the impending sizeable currency devaluation. Arize (1995) found that there is a long-term equilibrium between export and exchange rate fluctuations.

IV. Empirical Results

IV.1. Data Resource

Two types of data were collected from the Advanced Retrieval Econometric Modeling System (AREMOS) database and the Taiwan Economic Journal (TEJ). This study followed the formation of the ECU in building a CCU calculation. Reference is made to three weighted macroeconomic factors (i.e., GDP per capita, net reserve, and export volume) from Taiwan, Hong Kong, and Mainland China.

To investigate the relationship between CCU and the key factors in identifying the early warning indicators of currency crises, quarterly data from 1992Q1 to 2007Q4 were used while simultaneously observing time series and cross-section data.

This study used the LIMDEP software package in programming the ordered probit model to detect significant differences between the central exchange rate system of CCU and specific exchange rates against USD. The ordered probit model could only test non-random effects due to singularity problems.

To discuss the reactions between currency crises and macroeconomic factors, the data of currencies were divided into two groups: on specific exchange rate and on CCU exchange regimes. Table 1 covers all sample periods, which can be divided into the pre-crisis period (Table 2) and post-crisis period (Table 3). Table 4 shows that besides the real exchange rate and the ratio of current account to GDP, all other variables decreased after the 1997 Asian financial crisis. Obviously, the depreciated real exchange rate lowered GDP growth and decreased export growth. Weak stock markets were also observed after the crisis. CPI was

reduced by 5%, indicating that CCU areas started to control economic growth under a stable speed. In addition, the ratio of current account to GDP increased, and the ratio of M2 to reserves dropped, revealing that policy makers were better prepared for recovery.

IV.2. Findings

The results on the relationship between the selected variables and the occurrence of a possible currency crisis are shown in Tables 1–4. The test results from the ordered probit model are shown in Table 5.

Real exchange rate was significantly and negatively correlated with Specifications (1)-(5). Considering the formulation of real exchange rate in this study, when the domestic inflation rate increases or when the nominal exchange rate appreciates, the real exchange rate will consequently appreciate. Economic growth is always accompanied by the appreciation and inflation of exchange rates. Under the EWS hypothesis, these two factors may lead to a currency crisis. In terms of the survival model analysis on currency crisis, Chen (2002) found that an overvalued exchange rate would decrease the likelihood of exit time of crisis. On the other hand, an over-appreciated currency is likely to be associated with a higher probability of speculative attacks. Consistent with our empirical results, an appreciation of real exchange rate always leads to a higher likelihood of attack. The coefficients of real exchange rate under CCU were all lower than the specific exchange rates constructed by early warning indicators. This suggests that in the integration of economic environment and policies under a CCU regime, real exchange rates should be prioritized to ease the vulnerability of the currency.

Real interest rates represent a country's level of competitiveness, and an overvalued interest rate would cause a financial crisis. According to EWS's formulation, when interest rates increase, the probability of a currency crisis also increases. Interestingly, the results showed that real interest rate has a negative and statistically significant effect on the probability of a currency crisis. A significantly negative coefficient in the KLR model [Specification (3)] and in the Edison model [Specification (5)] revealed that the higher the real interest rate is the lower is the probability of a currency crisis. In the Mexico Tequila Crisis, high real exchange rates were sustained for a long period (Chen, 2000). Kaminsky et al. (1998) and Edison (2003) argued that central banks have brought their real interest rates up to help attract capital inflows and fend off speculative pressures. Besides, a CCU regime with relatively large coefficients indicates that maintaining a higher real interest rate will not only keep the currency value by attracting international capital inflow but also certainly strengthen the currency unification area to prevent a financial crisis.

Table 1 Statistic analysis for selected macroeconomic factors from 1992 to 2007

Variables	Notation	Mean	Standard dev.	Min.	Max.	Obs.
Real exchange rate	**REEX**	22.592	5.495	11.01	118.03	192
Real interest rate	**REINT**	0.049	0.021	0.014	0.095	192
Current account/GDP	**CAGDP**	-0.085	0.59	-1.938	1.094	192
CPI change	**CPICH**	3.173	5.362	-5.87	26.87	192
Stock index growth	**STOCGR**	0.036	0.184	-0.3	1.71	192
GDP growth	**GDPGR**	0.023	0.112	-0.81	0.359	192
M2/foreign reserve	**M2FR**	4.869	3.479	1.365	18.309	192
Export growth	**EXGR**	0.013	0.027	-0.058	0.105	192

Table 2 Statistic analysis for selected macroeconomic factors from 1992 to 1996

Variables	Notation	Mean	Standard dev.	Min.	Max.	Obs.
Real exchange rate	**REEX**	17.474	7.119	11.001	56.9	60
Real interest rate	**REINT**	0.067	0.012	0.048	0.095	60
Current account/GDP	**CAGDP**	-0.181	0.581	-1.938	0.577	60
CPI change	**CPICH**	8.648	5.994	1.71	26.87	60
Stock index growth	**STOCGR**	0.066	0.269	-0.279	1.711	60
GDP growth	**GDPGR**	0.038	0.042	-0.076	0.108	60
M2/foreign reserve	**M2FR**	7.289	4.601	1.727	18.309	60
Export growth	**EXGR**	0.016	0.032	-0.058	0.105	60

Table 3 Statistic analysis for selected macroeconomic factors from 1997-2007

Variables	Notation	Mean	Standard dev.	Min.	Max.	Obs.
Real exchange rate	**REEX**	27.373	2.31	35.867	118.033	132
Real interest rate	**REINT**	0.041	0.018	0.014	0.088	132
Current account/GDP	**CAGDP**	-0.042	0.591	-1.43	1.094	132
CPI change	**CPICH**	0.685	2.404	-5.87	8.03	132
Stock index growth	**STOCGR**	0.023	0.127	-0.3	0.338	132
GDP growth	**GDPGR**	0.016	0.132	-0.809	0.359	132
M2/foreign reserve	**M2FR**	3.769	2.052	1.365	8.363	132
Export growth	**EXGR**	0.012	0.024	-0.049	0.066	132

Table 4 The mean of variables: Pre-crisis (1992 to 1996) and Post-crisis (1997-2007)

Variables	Notation	Pre-crisis	Post-crisis	Change
Real exchange rate	REEX	17.474	22.592	↑
Real interest rate	REINT	0.067	0.049	↓
Current account/GDP	CAGDP	-0.181	-0.085	↑
CPI change	CPICH	8.648	3.174	↓
Stock index growth	STOCGR	0.066	0.036	↓
GDP growth	GDPGR	0.038	0.023	↓
M2/foreign reserve	M2FR	7.289	4.869	↓
Export growth	EXGR	0.016	0.012	↓

Table 5 Test Results: ordered probit models

Variables Notation		ERW		KLR		Edison	
		CCU	Exchange rate	CCU	Exchange rate	CCU	Exchange rate
Specification		(1)	(2)	(3)	(4)	(5)	(6)
Constant		-0.737 (0.07)*	-1.59 (0.01)***	-0.974 (0.06)*	-2.032 (0.01)***	-0.943 (0.02)**	-1.841 (0.01)***
Real exchange rate	REEX	-0.305 (0.02)**	-0.325 (0.02)**	-0.275 (0.01)***	-0.348 (0.03)**	-0.268 (0.01)***	-0.195 (0.22)
Real interest rate	REINT	-15.589 (0.19)	-1.784 (0.85)	-17.02 (0.04)**	-0.579 (0.94)	-21.745 (0.01)***	4.035 (0.69)
Current account/GDP	CAGDP	-0.487 (0.27)	-0.312 (0.65)	-0.083 (0.79)	0.162 (0.74)	-0.383 (0.43)	-0.149 (0.83)
CPI change	CPICH	0.256 (0.24)	0.248 (0.05)**	0.293 (0.03)**	0.254 (0.04)**	0.328 (0.07)*	0.139 (0.32)
Stock index growth	STOCGR	-4.682 (0.10)*	-1.648 (0.27)	-1.416 (0.71)	-2.378 (0.61)	0.369 (0.09)*	-2.114 (0.57)
GDP growth	GDPGR	1.737 (0.06)*	1.125 (0.05)**	0.387 (0.01)***	0.989 (0.07)*	-1.321 (0.01)***	0.65 (0.32)
M2/reserves	M2FR	0.074 (0.47)	0.121 (0.18)	0.099 (0.70)	0.213 (0.43)	0.082 (0.81)	0.097 (0.47)
Export growth	EXGR	-4.078 (0.01)***	-6.678 (0.14)	2.248 (0.10)*	-5.509 (0.06)*	1.098 (0.40)	-5.229 (0.10)*

Note: P-values are shown in parentheses. * P<0.1. ** P<0.05. ***P<0.01.

In the second generation of the currency crisis theory, inflation was a crucial factor. Dallas and Stockman (1993) indicated that raising the money supply to depress inflation could not solve the self-fulfilling crisis. This supports our expectation that a higher inflation would lead to a greater probability of financial crises. In Specifications (2)–(5), the estimates of CPI change appeared to influence strongly and positively the occurrence of a crisis, indicating that the inflation rate may induce financial weaknesses associated with the occurrence of a crisis. In order to lessen the pressure from the occurrence of a crisis, Chen, Wang, and Lin (2001) and Chen and Hsiao (2006) indicated that the inflation rate is an effective macroeconomic variable in affecting ACU.

When foreign investors have no confidence in one country's economy, the stock index may decline, inducing capital outflow and lowering foreign reserves. In effect, a currency crisis is stimulated. In the ERW model [Specification (1)], stock index growth showed a negative significant effect on the probability of a currency crisis. Unexpectedly, the results strongly suggest that stock index growth positively reacts to the probability of a currency crisis in the Edison model [Specification (5)]. This supports the theory that one year prior to a currency crisis, the stock index will rapidly vibrate (Edison, 2003).

Frankel and Rose (1996) found that the negative effect of current/GDP could reinforce the predictive accuracy of forecasts. However, all the negative impacts of current/GDP were found to be insignificantly correlated with the probability of a currency crisis. Berg and Pattillo (1999) also indicated that current/GDP is not significant in crisis forecasting.

With regard to GDP growth and export growth, the results showed that the coefficients of export growth were negative, and some of them [i.e., Specifications (2), (4), and (6)] were significantly correlated with the occurrence of crises. However, the findings in the ERW and KLR methods [Specifications (1) and (3)] have produced mixed results for export growth relative to the probability of crisis. This reveals that trading enhances the performance of economic systems in deflecting currency crises, but an overheated economic environment may hold some weaknesses for speculators to attack.

Under the third-generation currency crisis theory, if the trade partnership between two countries is stronger, a currency crisis is likely to occur. Consistently, the coefficients of GDP growth were significantly positive in Specifications (1)-(4). CCU areas all rely on exports to support economic growth. Hence, a higher GDP growth leads to a greater possibility of a currency crisis. However, controlling GDP growth under a safer range may help reduce the probability of a currency crisis.

IV.4. Marginal effect

By observing marginal effect, the study provided a better interpretation of the influence of each factor to the currency crisis in three EWS methods (see Table 6). Under ordered probit models, the marginal effect was divided into three parts: Y=0, Y=1, and Y=2. Y=0 indicates that there is no currency crisis risk and shows a different direction with the sign of corresponding coefficients. On the other hand, Y=2 denotes a dangerous level. A currency crisis might eventually occur, and it has the same direction as the selected variables. Similarly, Y=1 shows that an allowance of some risk exists. The results showed the direction of marginal effect when Y=1 is similar to when Y=2.

Using the ERW method, in Y=1, real interest rate, current account/GDP, CPI change, stock index growth, and GDP growth performed well under the CCU regime. The CCU regime revealed similar results in marginal effect, except for stock index growth in the Edison method. In addition, using the KLR method, real exchange rate, real interest rate, and CPI change had greater performances under the CCU regime. The same was observed from specific exchange rates at Y=1. This provides evidence that a CCU regime can effectively reduce the possibility of a currency crisis at Y=1 as compared to Y=2 regardless of the Edison method. Chen, Wang, and Lin (2001) and Hsiao (2004) found that Asian currency unification could exert minor influences on currency crises. The estimates of marginal effect for real exchange rate, CPI change, M2/reserves, and current account/GDP appeared to have negligible effects. Moreover, real interest rate, stock index growth, and GDP growth played pivotal roles in the marginal effect in many specifications. In the CCU regime of Taiwan, Hong Kong, and Mainland China, governments should maintain higher real interest rates to increase capital inflow and to fend off speculative attacks. By excluding the Edison method, policy makers should make an effort for stimulating stock markets and stabilizing GDP growth to alleviate the impact of crises. CCU countries could prioritize these three variables in lessening the shocks from crises or in decreasing the probability of a currency crisis efficiently.

Table 6 Marginal effect in ordered probit model

Variables Notation		ERW						KLR						Edison					
		CCU Rate			Exchange rate			CCU Rate			Exchange rate			CCU Rate			Exchange rate		
		Y=0	Y=1	Y=2	Y=0	Y=1	Y=2	Y=0	Y=1	Y=2	Y=0	Y=1	Y=2	Y=0	Y=1	Y=2	Y=0	Y=1	Y=2
Constant		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Real exchange rate	REEX	0.054	-0.031	-0.024	0.060	-0.033	-0.027	0.058	-0.035	-0.023	0.062	-0.031	-0.031	0.049	-0.019	-0.031	0.031	-0.017	-0.014
Real interest rate	REINT	2.764	-1.557	-1.207	0.330	-0.183	-0.148	3.611	-2.177	-1.434	0.103	-0.052	-0.051	3.990	-1.502	-2.488	-0.643	0.352	0.291
Current account/GDP	CAGDP	0.086	-0.049	-0.038	0.058	-0.032	-0.026	0.018	-0.011	-0.007	-0.029	0.015	0.014	0.070	-0.027	-0.044	0.024	-0.013	-0.011
CPI change	CPICH	-0.045	0.026	0.02	-0.046	0.025	0.021	-0.062	0.038	0.025	-0.045	0.023	0.022	-0.060	0.023	0.038	-0.022	0.012	0.010
Stock index growth	STOCGR	0.83	-0.468	-0.363	0.305	-0.169	-0.136	0.301	-0.181	-0.119	0.421	-0.212	-0.209	-0.068	0.026	0.042	0.337	-0.185	-0.152
GDP growth	GDPGR	-0.308	0.174	0.135	-0.208	0.115	0.093	-0.082	0.050	0.033	-0.175	0.088	0.087	0.242	-0.091	-0.151	-0.104	0.057	0.047
M2/reserves	M2FR	-0.013	0.007	0.006	-0.023	0.012	0.01	-0.021	0.013	0.008	-0.038	0.019	0.019	-0.015	0.006	0.009	-0.015	0.008	0.007
Export growth	EXGR	0.723	-0.407	-0.316	1.236	-0.684	-0.552	-0.477	0.288	0.190	0.975	-0.492	-0.483	-0.202	0.076	0.126	0.834	-0.457	-0.377

IV. 5. Predictive accuracy

To confirm the predictive accuracy of EWS methods, all the Chi-squared and forecast performance data were compared. All chi-squared data were higher than 3.84 (see Table 7), indicating that all EWS methods were reliable in detecting currency crises and thereby helping decrease financial damages in advance. All the accuracy levels of the prediction models were higher than 80%. The CCU regime performed better in forecasting a currency crisis than a specific exchange rate.

Table 7 Predicting accuracy in ordered probit model

Measure of fit	ERW		KLR		Edison	
	No random effects		No random effects		No random effects	
	CCU	Exchange Rate	CCU	Exchange rate	CCU	Exchange rate
Chi-squared	33.747	17.303	15.408	28.807	16.191	13.582
Correctly Predict on currency crisis	0.859	0.833	0.854	0.848	0.885	0.869

V. Conclusion

Regional integration could facilitate cooperation among member countries and could lessen outside shocks caused by currency crises. Robert Mundell advocated regional integration, such as the establishment of the European Union, which has brought numerous benefits to Europe. After the 1997 Asian financial crisis, currency unification remained a controversial topic among Asian countries. This study used empirical results in examining a possible CCU regime to help prevent members from being plunged into a currency crisis. It also developed an ordered probit model to identify the factors influencing crisis levels.

In the ordered probit model, real exchange rate was the most significant factor affecting the probability of crises. An overvalued real exchange rate is highly associated with currency crisis. Moreover, the results show that the coefficients of real exchange rate in the CCU regime are lower than those in specific exchange rates. This implies that in preventing speculative attacks, CCU areas should stabilize real exchange rates to avoid the uncontrollable change of currencies. The significant negative signs of real interest rates from the KLR and Edison methods indicate that policymakers should maintain attractive real interest rates to facilitate international capital inflows. Meanwhile, export growth plays an ambiguous role. It may facilitate economic growth to fend off crisis. On the other hand, trading linkages may also cause a currency crisis. Economic growth, accompanied by higher CPI change and real exchange rate appreciation, is a crucial factor affecting the occurrence of currency crises. Consistent with our hypothesis, an over-appreciated real exchange rate and

higher CPI change will induce a currency crisis. The results showed that to prevent this, CCU areas should adopt reliable policies, and policy makers should focus not only on economic growth but also on stabilizing economic factors.

With regard to marginal effects, CCU members should focus on four indicators: real interest rate, stock index growth, GDP growth, and export growth, which play pivotal roles in the CCU regime in terms of reducing currency vulnerability. Policy makers should try to facilitate stock markets to prevent overheating and to stabilize GDP growth to alleviate the impacts of crises. At crisis level Y=1, the marginal effect of the CCU regime is greater than specific exchange rates, except for the ratio of M2 to foreign reserves and export growth. The results indicate that when the economy encounters a potential currency crisis, the CCU regime could perform well in reducing the probability of crisis better than the performance of specific exchange rates.

According to predictive accuracy, the adoption of a CCU regime may successfully predict the occurrence of currency crises. All accuracy rates of the prediction models were higher than 80%. In addition, the CCU regime performed better in forecasting a currency crisis than specific exchange rates. After observing the p-values of the crisis levels, Y=0, 1, and 2, interesting results were also found. Regardless of the kind of EWS and methodology models adopted, the predictive capability of the CCU's crisis level is more statistically significant than that of specific exchange rates. This supports the findings of Chen, Wan, and Lin (2001) that an ACU could successfully predict currency crises and lower the risk and shocks induced by financial crises. This research proves that a CCU regime could lessen the probability of currency crises, as well as fend off speculative attacks.

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