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Analysis on β and σ Convergences of East Asian Currencies[*]

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Abstract

This paper investigates recent diverging trends among East Asian currencies as well as recent movements of the weighted average value of East Asian currencies (Asian Monetary Unit: AMU) and deviations (AMU Deviation Indicators) of the East Asian currencies from the average values by β and σ convergence methods. Our empirical analysis shows that linkages with the US dollar have been weakening since 2001 or 2002 for some of the East Asian countries. On the other hand, the monetary authority of China continues stabilizing the exchange rate of the Chinese yuan against the US dollar even though it announced its adoption of a currency basket system. It is found that the weighted average of East Asian currencies has been appreciating against the US dollar while depreciating against the currency basket of the US dollar and the euro until the global financial crisis in 2008. Also, the analytical results on β and σ Convergences show that deviations among the East Asian currencies have been widening in recent years, reflecting the fact that these countries' monetary authorities are adopting a variety of exchange rate systems. In other words, a coordination failure in adopting exchange rate systems among these monetary authorities increases volatility and misalignment of intra-regional exchange rates in East Asia.

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1. Introduction

The monetary authorities of East Asian countries learnt a lesson that it is inadequate for a country with close economic relationships not only with the United States but also other countries to adopt either an official or *de facto* dollar-peg system from the experience of the Asian currency crisis in 1997. The monetary authorities have changed to more flexible exchange rate systems, including free-floating and managed floating systems. Moreover, the Chinese government announced on July 21, 2005 that the monetary authority will change its exchange rate system from the *de facto* dollar-peg system to a managed floating exchange rate system with reference to a currency basket. These trends might contribute to solving a coordination failure in choosing exchange rate systems among East Asian countries as shown in Ogawa and Ito (2002) if these countries are actually adopting a similar type of exchange rate system.

This paper's objective is to investigate recent diverging trend in East Asian currencies by β and σ convergence methods proposed by Adam *et al.* (2002). These methods enable us to understand whether East Asian currencies converge to their average level or AMU, which is the weighted average of East Asian currencies and created by Ogawa and Shimizu (2005). If these currencies are not converged, or the monetary authorities of East Asian countries continue adopting a variety of exchange rate systems, they may face coordination failure in exchange rate systems. This situation will likely increase volatility and misalignment of the intra-regional exchange rates in East Asia.

Two recent events are likely to affect movements of East Asian currencies. First, the Chinese government made announcement of its exchange rate regime reform (RMB reform) that includes shifting its target from the US dollar to a currency basket on July 21, 2005. After the RMB reform, the Chinese yuan is expected to target a currency basket similarly with other East Asian currencies, some of which have linkages with not only the US dollar but also the euro and the Japanese yen. Secondly, the recent subprime mortgage shock, which happened on August 8, 2007, might affect linkages among the East Asian currencies by changing capital flows in international financial markets. We divide the whole sample period into three sub-sample periods based on the above events to investigate any changes in the movements and convergences of East Asian currencies.

In the next section, we use the methodology of Frankel and Wei (1994) to investigate actual exchange rate policies conducted by the monetary authorities of East Asian countries.[1] We analyze linkages of each of East Asian currencies with major international currencies during three sub-sample periods: a pre-RMB reform period (1/3/2000 to 7/20/2005), a post-RMB reform period (7/21/2005 to 8/7/2007), and a subprime mortgage problem period (8/8/2007 to 2/27/2009). We obtain that a currency basket is targeted in some countries while the monetary authorities of the other

[1] Ogawa and Yoshimi (2008, 2007) investigated them during a period from 1999 to 2007

countries including China have still kept targeting stabilization of the home currency against the US dollar only. In the third section, we use the AMU and AMU Deviation Indicators in order to investigate movements of the average value of East Asian currencies and deviations among them in recent years. The average value is found to be appreciating against the US dollar while depreciating against the currency basket of the US dollar and the euro until the global financial crisis in 2008. Also, a weighted average of the AMU Deviation Indicator is calculated in order to statistically investigate recent deviation developments among East Asian currencies. Deviations are found to have been widening in recent years although they temporally dropped early 2008. Moreover, β and σ convergence methods are used to analyze statistically deviations of East Asian currencies. The analytical results on β and σ convergence support these results although unit root tests are significantly rejected in several specifications during the pre-RMB reform period The fourth section of the paper points out coordination failure in exchange rate systems in East Asia and suggests that East Asian monetary authorities should seek coordination in exchange rate policies. Specifically, all the ASEAN+3 member countries' monetary authorities should agree on an arrangement to create a common unit of account that consists of a basket of regional currencies for coordinated exchange rate policy. In the conclusion, we point out that the widening deviations among the East Asian currencies reflect that East Asian monetary authorities are adopting a variety of exchange rate systems. Moreover, the coordination failure increases volatility and misalignment of intra-regional exchange rates in East Asia.

2. Linkages of East Asian currencies with three main currencies

We (Ogawa and Yoshimi (2007, 2008)) used the methodology of Frankel and Wei (1994) to investigate actual exchange rate systems and policies conducted by the monetary authorities of East Asian countries during a period from 1999 to 2007. [2] This chapter extends its sample period to 2008 and early 2009 to follow up the investigation. Its empirical analysis is conducted to investigate what linkage trends each East Asian currency actually has with three major currencies: the US dollar, the euro, and the Japanese yen. For this purpose, the empirical analytical method of Frankel and Wei (1994) is used to analyze these linkages for three sub-sample periods: a pre-RMB reform period (1/3/2000 to 7/20/2005), a post-RMB reform period (7/21/2005 to 8/7/2007), and a subprime mortgage problem period (8/8/2007 to 2/27/2009). The ASEAN10 countries (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam), China, and South Korea are covered, although the sample periods for Cambodia, Laos, and Myanmar cover only from 2003 to early 2009 due to data constraints.

Frankel and Wei (1994) assume the Swiss franc as a numeraire in the denomination of

[2] Kawai and Akiyama (1998, 2000) conducted a method to investigate exchange rate policies of East Asian countries.

exchange rates. Daily data of exchange rates are used to conduct regression of log differences of a local currency (in terms of the Swiss franc) on log differences of the three major currencies (in terms of the Swiss franc) for each sub-sample period. The regression for each sub-sample period shows trend linkages of each East Asian currency with the three major currencies during the period.[3]

The regression equation is as follows:

$$\Delta \log e^{HOME/SFR} = a_0 + a_1 \Delta \log e^{USD/SFR} + a_2 \Delta \log e^{EURO/SFR} + a_3 \Delta \log e^{JPY/SFR} + \varepsilon_t \quad (1)$$

Where $e^{HOME/SFR}$: exchange rate of a home currency in terms of the Swiss franc, $e^{USD/SFR}$: exchange rate of the US dollar in terms of the Swiss franc, $e^{EURO/SFR}$: exchange rate of the euro in terms of the Swiss franc, $e^{JPY/SFR}$: exchange rate of the Japanese yen in terms of the Swiss franc.

Table 1 shows results of the regression for each of the East Asian currencies.

(1) Brunei dollar

The monetary authority of Brunei has a currency board backed by the Singapore dollar. Accordingly, the Brunei dollar should have the same movements as the Singapore dollar. Linkages of the Brunei dollar with the three major currencies show almost the same trend as with the Singapore dollar. It has the strongest linkage with the US dollar and the weakest linkage with the yen among the three major currencies. The estimated coefficient on the US dollar is stable during the sample period. Further, the estimated coefficient on the euro increases while that on the yen gradually decreases.

(2) Cambodian riel

The Cambodian riel was fixed to the US dollar for nearly the entire analyzed period from 2003 to early 2009. Linkage with the US dollar remained at levels between 0.9104 and 1.0039. Coefficients on the euro and the yen were not statistically significant during the sample period.

(3) Chinese yuan

On July 21, 2005, the Chinese government announced it would change the Chinese exchange rate system from a dollar-peg system to a managed floating system with reference to a currency basket. Linkage of the Chinese yuan with the US dollar was completely perfect before the announcement, as shown by the coefficients on the US dollar of 1.0002 in the pre-RMB reform period. The linkage with the US dollar decreases to a level of 0.9541 in the post-RMB reform period.

[3] McKinnon (2001) and Ogawa (2002, 2004) conducted a similar method to investigate the dynamics of the coefficients. Ogawa and Sakane (2006) used the Kalman filter method to investigate these dynamics for the Chinese yuan.

Further, coefficients on the euro and the yen increase in the post-RMB reform period although the linkage with the euro is not significantly estimated. The coefficients (between 0.9541 and 1.0002) were much higher than China's trade shares (about 15%) with the United States in recent years. [4] The linkages of the Chinese yuan with the euro and the yen were statistically insignificant despite the Chinese government's announcement of the exchange rate system reform.

(4) Indonesian rupiah

Linkage of the Indonesian rupiah with the US dollar was over unity in the subprime mortgage problem period. It reached the level of 1.0015 in the subprime mortgage problem period. Coefficients on the euro and the yen were not statistically significant in most sub-sample periods. The adjusted R2 has been very low over the sample period especially for the first sub-sample period. This implies that the Indonesian rupiah was influenced by factors other than the three major currencies.

(5) Korean won

The IMF classifies that the monetary authority of South Korea adopts an independent floating exchange rate system. Linkage of the Korean won with the US dollar has a decreasing trend, with a high of 0.9050 in the pre-RMB reform period. Linkage decreased and reached a level of 0.7370 in the subprime mortgage problem period. In the post-RMB reform period, linkage with the euro significantly increased. Further, linkage with the yen is always statistically significant although estimated coefficients are very low.

(6) Lao kip

The Lao kip was fixed to the US dollar for nearly the entire analyzed period. Linkage with the US dollar stayed at between 0.8770 and 0.9821. The coefficients on the euro and the yen were not found to be statistically significant in many cases. Especially, those on the yen were not significantly estimated in all the sub-sample periods including the case with full samples.

(7) Malaysian ringgit

On July 21, 2005, the monetary authority of Malaysia immediately followed the Chinese government's announcement and announced it would change from a dollar-peg exchange rate system to a managed floating system with reference to a currency basket. Linkage of the Malaysian ringgit with the US dollar takes a level of 0.8930 in the pre-RMB reform period that is the highest level in all the three sub-sample periods. Linkage with the US dollar decreased to 0.8419 in the subprime mortgage problem period.

[4] See Ogawa and Sakane (2006) for details of the Chinese exchange rate system reform.

(8) Myanmar kyat

The Myanmar kyat was fixed to the US dollar for the entire analyzed period. Linkages with the US dollar stayed at levels between 0.8982 and 0.9872. The linkage with the US dollar reached at a level of 0.9872 in the subprime mortgage problem period. The linkages with the euro and the yen were not statistically significant in most cases.

(9) Philippine peso

The Philippine peso had strong linkage with the US dollar during the sample period. The coefficient on the US dollar was 0.8831 and the highest in the pre-RMB reform period. It has been decreasing since during the sample period and reached at a level of 0.8637. The Philippine peso has some linkages with the euro and the yen in the third and the first sub-sample period, respectively.

(10) Singapore dollar

It is known that the Monetary Authority of Singapore uses a currency basket system where it targets the Singapore dollar to a currency basket which includes its major trading partners' currencies. The currency basket system reflects in an analytical result that coefficients on the three major currencies were statistically significant over the sample period. The linkage of the Singapore dollar with the US dollar was relatively high in the subprime mortgage problem period and took a level of 0.7812. We can see that the results for the Singapore dollar is very similar to those for the Brunei dollar as the monetary authority of Brunei has a currency board backed by the Singapore dollar.

(11) Thai baht

The Thai baht has linkages with not only the US dollar but also the euro and the Japanese yen. The coefficient on the US dollar was 0.7115 in the pre-RMB reform period and then increased to a level of 0.9117 in the subprime mortgage problem period. Coefficients on the euro and the yen have decreasing trends and both of them are not significantly estimated by the subprime mortgage problem period.

(12) Vietnamese dong

The monetary authority of Vietnam has been focusing only the exchange rate of the Vietnamese dong in terms of the US dollar during the sample period. The coefficients on the US dollar are between 0.9976 and 1.0127 during the sample period while those on the euro and the yen are not significantly estimated. Moreover, the coefficients of determination were almost unity, which implies that fluctuations of the Vietnamese dong can be explained only by those of the US dollar.

The empirical results show that the linkage with the US dollar has been weakening from the first to the second sub-sample period for all the sample currencies except for the Thai baht and the Vietnamese dong although it has been strengthened after the global financial crisis occurred summer 2007 for all the currencies except for the Korean won, the Malaysian ringgit, and the Philippine peso. The estimated coefficient on the US dollar has decreasing trend for the Korean won, the Malaysian ringgit, and the Philippine peso during the sample period, and increasing trend for the Thai baht and the Vietnamese dong. Especially, the Malaysian ringgit has weakened against the US dollar since when the monetary authority of Malaysia followed the monetary authorities of China to announce the exchange rate system reforms. On the other hand, the linkage between the Chinese yuan and the US dollar was strengthened in the last sub-sample period although it had been weakened once in the second sub-sample period. This shows that the monetary authority of China continues to stabilize the exchange rate of the Chinese yuan against the US dollar. All three coefficients on the US dollar, the euro, and the yen were statistically significant for the Brunei dollar and the Singapore dollar in all the sub-sample periods including the case with full samples. This is because the Brunei dollar follows the Singapore dollar which is targeted to a currency basket with currencies of Singapore's major trading partners as mentioned. The monetary authority of Korea is targeting its exchange rate in terms of not only the US dollar but also the euro and the yen at least after the RMB reform.

3. Widening deviation among East Asian currencies

3.1. The deviation measurement

Next we show deviation measurements of each East Asian currency from an average of the currencies to investigate widening deviation among them. Ogawa and Shimizu (2005) created an Asian Monetary Unit (AMU) as a regional unit for East Asia that is a weighted average of its currencies: those of the ASEAN10+3 (ASEAN10 with China, Japan, and South Korea) economies. The weight of each currency in the basket is based both on countries' respective shares of GDP measured at purchasing power parity (PPP), and their trade volumes (the sum of exports and imports) in the total of sampled countries. These two measurements are calculated as the average of the most recent three years (2004-2006) for which data is available. Also, an AMU Deviation Indicator is measured for each East Asian currency's deviation from the AMU.[5] The AMU Deviation Indicators are set at zero during their benchmark period of two years in 2000 and 2001 when trade imbalances of East Asian countries were at their smallest in the period of 1999-2006.

Figure 1 shows a recent trend in the AMU nominal exchange rate in terms of a US dollar and euro currency basket as well as in terms of the US dollar and the euro separately. The currency basket is composed 65% of the US dollar 35% of the euro based on trade shares of the East Asian

[5] Both the AMU and AMU Deviation Indicators are available at a website of the Research Institute of Economy, Trade and Industry (http://www.rieti.go.jp/users/amu/en/index.html)

countries with the US and the euro area in 2001-2003 in order to reflect the value of the AMU in terms of major trading partners' currencies. Figure 1 shows that the AMU has been gradually depreciating against the currency basket of the US dollar and the euro until May 2003, about 10% decline compared with the benchmark years of 2000 and 2001. However, it reversed its trend to upward direction and got back to almost the same level as in the benchmark years by October 2008. When viewing the currencies separately, the AMU has been gradually appreciating against the US dollar during the sample period though depreciating since April 2008. It has been gradually depreciating against the euro until July 2008 though rapidly appreciated since then.

Figure 2 shows movements in deviations of East Asian currencies against the AMU in terms of nominal exchange rates from the benchmark years of 2000 and 2001. The Korean won and the Thai baht has characteristic movements in recent years. The Korean won were overvalued against the AMU or a weighted average of East Asian currencies from the end of 2004 to early 2008. It was overvalued by more than 20% compared with the benchmark years especially from March 2006 to July 2007. However, the Korean won has been depreciating too quickly since the end of 2007. The Thai baht was appreciating very quickly from the end of 2006 to August 2007. It was overvalued by about 30% compared with the benchmark years. However, the Thai baht has been depreciating quickly since then. On the other hand, the Japanese yen and the Chinese yuan have been appreciating in recent months.

Figure 3 shows movements in deviations of East Asian currencies against the AMU in terms of real exchange rates from the benchmark years. The Real AMU Deviation Indicators of East Asian currencies were limited within plus 20% and minus 10% during a period from 2000 to 2001. The Indonesia rupiah and the Lao kip have appreciated against the AMU in terms of real exchange rates because of higher inflation since 2003. The Korean won was overvalued against the AMU also in terms of real exchange rates due to the appreciation of the nominal exchange rate from the end of 2004 to October 2007 although it has been depreciating quickly due to depreciation of nominal exchange rate of the Korean won. The Thai baht has quickly appreciated in terms of real exchange rates because of the quick appreciation of the nominal exchange rate since from the end of 2006. On the other hand, the Japanese yen was depreciating because of a combination of yen depreciation in terms of nominal exchange rate and the deflation in prices from January 2005 to July 2007. It recorded that it was undervalued by 30% compared with the benchmark years in July 2007. However, the Japanese yen has been appreciating in terms of real exchange rate since August 2007.

Figure 4 and 5 show movements in the weighted averages of the above Nominal and Real AMU Deviation Indicators for all of the East Asian currencies, respectively. The two weighted averages of the AMU Deviation Indicators are calculated according to the following equation:

$$\text{Weighted average of AMU DI} = \sqrt{\sum_i \left(w_i DI_{i,t}\right)^2} \quad (2)$$

where $DI_{i,t}$: AMU Deviation Indicator for currency i at time t, w_i : weight on currency *i*. The weights are based on the arithmetic of the GDP measured at PPP and trade shares according to the calculation of the AMU.

Figure 4 shows that the weighted average of the Nominal AMU Deviation Indicator rapidly decreased after it recorded a level of 3.5% in January 2002. It stayed at a lower level, between 0.5% and 2.0%, from May 2002 to December 2004. However, it has been increasing since January 2005 and it reached the level of 4.7% in July 2007 although it has decreased to a level of 1.3% in March 2008. Further, the Nominal AMU Deviation Indicator rapidly increased since March 2008 and it recorded the highest level of 5.1% in November 2008.

Figure 5 shows that the weighted average of the Real AMU Deviation Indicator briefly decreased after it recorded at a level of 4.0% in February 2002. It stayed between 2.5% and 3.2% from 2002 to 2004. However, it has been increasing since from the end of 2004 and recorded its highest level of 9.3% in July 2007. These results imply that deviations of East Asian currencies from the AMU in terms of both nominal and real exchange rates have been, on average, increasing. However, we have to check the diverging trend of the AMU formally since the Nominal and Real AMU Deviation Indicators, respectively, decrease from the mid 2007 to the mid 2008 and since July 2007. This is the main contribution of this paper and is dealt with in the next section.

Contributions of each country's AMU Deviation Indicator to the weighted averaged AMU Deviation Indicator are reported in Figures 6 to 9. The contributions are calculated daily for the Nominal AMU Deviation Indicators and monthly for the Real AMU Deviation Indicators. From the contributions, the averages of them are calculated yearly. We also calculate averages for the two periods divided by the Chinese reform on July 21, 2005. Table 2 reports the top three contributors each year and each period.

Generally speaking, movements in the Japanese yen and the Chinese yuan have contributed to movements in the weighted average of the AMU Deviation Indicators in the pre-RMB reform period. In the post-RMB reform period, the Japanese yen and the Korean won increased their contributions though the Chinese yuan decreased its contribution. This means that the upward trend of the weighted average of AMU Deviation Indicators is mainly caused by increasing deviations of the Japanese yen and the Korean won from the AMU. The Japanese yen and the Korean won remain to be main contributors in the subprime mortgage problem period while the contribution of the Chinese yuan is lower than these two currencies. The Chinese yuan decreased its contribution after the reform of exchange rate regime because it nearly maintained its degree of deviation from the AMU

though the other countries increased their deviation in the post-RMB reform period and the sub-prime problem period, as shown in Figure 2 and 3. Accordingly, the Chinese exchange rate system reform is not likely to be a direct factor of decreasing contribution of the Chinese yuan to the weighted average of the AMU Deviation Indicators. Rather the dollar pegging system that was adopted by the Chinese government before July 21, 2005 contributed to deviation of the East Asian currencies.

3.2. β-convergence and σ-convergence of East Asian currencies

The results in the previous section imply that the East Asian currencies are diverging during the sample period although one can also observe the phases in which deviations look to be reducing. In this section, we try to answer the question "Are deviations among the East Asian currencies widening?" adopting the methods called β-convergence and σ-convergence. By estimating the following equation, we analyze whether the AMU Deviation Indicators converge among the sample period and, if they are converging, how fast the speed of their convergence is.

$$\Delta DI_{i,t} = \mu_i + \beta_i DI_{i,t-1} + \sum_{j=1}^{p_i} \gamma_j \Delta DI_{i,t-j} + \varepsilon_{i,t}, \qquad (3)$$

where i and t denote the country and time indices. μ_i reflects an idiosyncratic factor in country i and the error term $\varepsilon_{i,t}$ denotes exogenous shocks to the difference of the AMU Deviation Indicators. p_i is the lag length for country i. A negative β_i indicates that deviation in countries with relatively large tend to converge to average level of sampled currencies more rapidly than in countries with relatively small. Further, the size of β_i is a direct measure of the speed of convergence. This method is called β-convergence test. Equation (3) can be estimated by panel unit root methods since a negative β_i is equivalent to the stationality of $DI_{i,t}$. We employ two methods advanced by Levin, Lin and Chu (2002, LLC hereafter) and Im, Pesaran and Shin (1997, IPS). In LLC test, the null and alternative hypotheses are $H_0 : \beta_i = \beta = 0$ and $H_1 : \beta < 0$, respectively. While LLC assume homogeneity in β_is, IPS allow β_i to differ across countries to avoid the heterogeneity bias. In IPS test, $H_0 : \beta_i = 0$ for all i, against the alternative $H_1 : \beta_i < 0$ for some of i.

To measure the degree of convergence at each point in time and assess whether DIs are converging to their average level during the sample period, the following equation is estimated.

$$\Delta\sigma_{i,t}^2 = \kappa + \eta\sigma_{i,t-1}^2 + \sum_{j=1}^{p_i} \lambda_j \Delta\sigma_{i,t-j}^2 + \nu_{i,t}, \qquad (4)$$

where $\sigma_{i,t}^2$ is variance of the AMU Deviation Indicator in country i at time t, and $\nu_{i,t}$ denotes

exogenous shocks. A negative η indicates that the deviation among the AMU Deviation Indicators tend to decrease when it is high. Equation (4) can be estimated by Augmented Dickey-Fuller (ADF) unit root test methods as a negative η suggests that the sequence of $\sigma_{i,t}^2$ follows stationary process. Thus, the null and alternative hypotheses are $H_0 : \eta = 0$ and $H_1 : \eta < 0$, respectively. We also employ Phillips-Perron (PP) method to allow the autocorrelation in the stochastic shocks to $\sigma_{i,t}^2$.

These approaches were proposed by Adam *et al.* (2002), and we employ them to investigate convergence or widening deviation among East Asian currencies. Adam *et al.* (2002) propose β-convergence and σ-convergence measurements, which they borrow from the economic growth literature, to investigate whether interbank interest rate among euro area countries relative to corresponding German rate have reduced or not. Ogawa and Kumamoto (2008) also used both the convergence measurements and showed the more detailed explanation of the methods.

Table 3 reports results of the ADF and PP tests for the averaged AMU deviation indicator and β-convergence tests (LLC and IPS tests) and σ-convergence test (ADF and PP tests) for the AMU deviation indicators of East Asian currencies. Table 3 (a) shows results in the case of using whole samples (January 3, 2000 to February 27, 2009). Lag lengths are selected based on the SBIC. We cannot reject the null hypothesis that the averaged AMU deviation indicator has unit root in all cases. Both the LLC and IPS tests have a result that they have no β-convergence among the East Asian currencies. Regarding σ-convergence, that is, cross-sectional dispersion among the East Asian currencies, we cannot reject the null hypothesis that the AMU deviation indicators of East Asian currencies have cross-sectional dispersion. Further, these results do not depend on whether a constant term is included and the choice between nominal and real data. These empirical results mean that the East Asian currencies are not converged during the whole sample period.

Table 3 (b) shows that both the LLC and IPS tests have a result that they partially have β-convergence among the East Asian currencies while we cannot reject the null hypothesis that the AMU deviation indicators of East Asian currencies have cross-sectional dispersion from the test of σ-convergence. On the other hand, Table 3 (c) and (d) show that both the LLC and IPS tests have a result that they have no β-convergence among the East Asian currencies while we cannot reject the null hypothesis that the AMU deviation indicators of East Asian currencies have cross-sectional dispersion from the test of σ-convergence in most cases.

The empirical results mean that East Asian currencies had partially β-convergence during the period from 2000 to the RMB reform. On the other hand, they have no σ-convergence over time during the whole sample period from January 2000 to January 2009.

4. Need for Regional Monetary Coordination

Ogawa and Ito (2002) pointed out possible coordination failure in choosing an exchange rate system and exchange rate policy in a game theory framework as long as one country's choosing the dollar-peg system has an adverse effect on others' choosing their own exchange rate systems through relative price effects. Ogawa (2007) conducted an empirical analysis on whether the dollar-pegging currencies adversely affected other East Asian countries' choices of exchange rate systems and exchange rate policies. They did not choose a desirable exchange rate system but rather the *de facto* dollar-peg system because the dollar-pegging countries continued to adopt official or *de facto* dollar-peg systems. In other words, this has been coordination failure. Accordingly, it is clear that regional coordination is needed for a desirable exchange rate regime instead of a formal or *de facto* dollar-peg system.

The officially and *de facto* dollar-pegging countries should adopt more flexible systems such as an intermediate exchange rate system that consists of both a currency basket and an exchange rate band. More flexible does not mean free-floating but intermediate exchange rate systems located between free-floating and dollar-peg. Although the monetary authority of China announced that it would shift to a managed floating exchange rate system with reference to a currency basket in July 2005, our analysis suggests that China has retained a *de facto* dollar-peg system. An intermediate exchange rate system seems to be desirable for East Asian countries, particularly China, due to the following two reasons.

First, under a currency basket system, monetary authorities do not target the US dollar but a combination of the dollar, yen, and euro, with a view toward international trade and foreign direct investment. East Asian countries have strong economic relationships in terms of international trade, foreign direct investment, and international finance with East Asia, Europe, and the US. Second, under an exchange rate band system, the monetary authorities set a range in which a currency is allowed to float freely. An exchange rate band gives a certain degree of latitude in monetary policy to the monetary authorities.

It is desirable for East Asian countries to stabilize exchange rates among intra-regional currencies as well as outside currencies such as the US dollar and the euro. For this purpose, the monetary authorities of East Asian countries should coordinate their exchange rate policies against outside currencies. They should also care about the yen because Japan plays a larger role in intra-regional economic relations.

The monetary authorities of ASEAN+3 member countries have through the Chiang Mai Initiative been strengthening regional monetary cooperation since the Asian Currency Crisis in 1997. Under the Initiative, a network of bilateral and multilateral swap arrangements was established for managing currency crises in ASEAN+3 countries. Via the Initiative, monetary authorities are supposed to conduct a surveillance process for preventing future currency crises. However, these

authorities have no standing institution for carrying out this process. Instead, they regularly meet as the Economic Review and Policy Dialogue (ERPD) in the ASEAN+3 Finance Deputy Ministers Meeting for surveillance of their macroeconomic performance and they focus only on domestic macroeconomic variables including GDP, inflation, and soundness of the financial sector.

The monetary authorities of East Asian countries should prevent biased changes in relative prices caused by US dollar depreciation under the different exchange rate systems. To do so, they have been trying to coordinate their exchange rate systems and exchange rate policies. Kawai, Ogawa, and Ito (2004) suggested that first the monetary authorities of ASEAN+3 should discuss the exchange rate issue as a part of their surveillance process, in addition to discussion on domestic macroeconomic policies and the soundness of financial sector. The exchange rates of these currencies against those of neighboring countries are indeed linked by terms of trade and competitive prices. Each country in East Asia has strong economic relationships with the others as well as with the US and Europe.

Exchange rates among the intra-regional currencies affect economic activities in each East Asian country via intra-regional trade, investments, and finance. The monetary authorities should not only consider movements of the exchange rates but also their deviations from regional averages and, in turn, their exchange rate policies.

The surveillance process in itself might not be sufficiently solid to preserve regional policy coordination in the long run because the monetary authorities from each country are not committed to policy coordination, they only may make limited contributions. A mechanism is needed that will compel the monetary authorities to be committed to the long-term regional policy coordination.

With this coordination it is necessary that all East Asian monetary authorities agree on an arrangement to create a common unit of account that consists of a basket of regional currencies. They might then commit to following the regional common unit of account in carrying out their exchange rate policy. An East Asian regional monetary unit could then be referred to in coordinating exchange rate policies. For this purpose, a common currency basket that includes regional currencies of the ASEAN+3 countries has been created. The ASEAN+3 Financial Ministers Meeting has launched to make a research group study a Regional Monetary Unit for coordinated exchange rate policy.

5. Conclusion

This paper investigated recent trends in exchange rate systems in East Asia. The IMF classification tells us that the monetary authorities of East Asian countries are adopting various exchange rate systems: free–floating, soft-peg, or currency board. The two corner solutions for exchange rate systems and intermediate exchange rate systems are found in East Asia. Exchange rate systems in East Asia are trending toward greater flexibility following the Asian Currency Crisis,

typified by the Chinese government's decision to change from a dollar-peg system to a managed floating exchange rate system with reference to a currency basket. Malaysia immediately followed suit after China's announcement it would change.

Empirical results show that linkages with the US dollar have been weakening since 2001 for some East Asian countries although we can observe a tendency to strengthen the linkages after the global financial crisis occurred summer 2007. The monetary authority of Singapore appears to have adopted a currency basket which includes the US dollar, the euro, and the yen. The monetary authority of South Korea is targeting its exchange rate in terms of not only the US dollar but also the yen. On the other hand, the Chinese yuan has yet to significantly change in terms of its linkage with the US dollar. The monetary authority of China continues to stabilize the exchange rate of the Chinese yuan against the US dollar despite its announcements of adopting a currency basket system.

Our analysis shows that the weighted average has been appreciating against the US dollar in recent years while it has been depreciating against the euro. Also deviations among the East Asian currencies have been widening as shown by the AMU Deviation Indicators and the weighted average of the AMU Deviation Indicators. The widening deviations reflect that the monetary authorities of East Asian countries are adopting a variety of exchange rate systems. In other words, coordination failure in exchange rate systems among these authorities increases volatility and misalignment of intra-regional exchange rates in East Asia.

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Table 1: Linkages of East Asian currencies to three main currencies

Brunei dollar	US dollar	euro	Japanese yen	Adj. R2
(a) Full samples	0.6632 ***	0.3280 ***	0.1458 ***	0.718
	(0.0121)	(0.0248)	(0.0092)	
(b) Pre-RMB reform period	0.6726 ***	0.1813 ***	0.2205 ***	0.717
	(0.0152)	(0.0365)	(0.0115)	
(c) Post-RMB reform period	0.6255 ***	0.3649 ***	0.1356 ***	0.807
	(0.0218)	(0.0566)	(0.0195)	
(d) Subprime mortgage problem period	0.6877 ***	0.3799 ***	−0.0684 ***	0.818
	(0.0239)	(0.0352)	(0.0178)	
Cambodia riel	US dollar	euro	Japanese yen	Adj. R2
(a) Full samples	0.9714 ***	−0.0067	0.0221	0.713
	(0.0226)	(0.0415)	(0.0186)	
(b) Pre-RMB reform period	0.9740 ***	0.1077	−0.0272	0.815
	(0.0311)	(0.0859)	(0.0294)	
(c) Post-RMB reform period	0.9104 ***	0.0191	0.0367	0.628
	(0.0414)	(0.1075)	(0.0371)	
(d) Subprime mortgage problem period	1.0039 ***	−0.0283	0.0274	0.693
	(0.0450)	(0.0665)	(0.0336)	
Chinese yuan	US dollar	euro	Japanese yen	Adj. R2
(a) Full samples	0.9895 ***	0.0066	0.0012	0.990
	(0.0023)	(0.0047)	(0.0017)	
(b) Pre-RMB reform period	1.0002 ***	−0.0005	−0.0002	1.000
	(0.0002)	(0.0006)	(0.0002)	
(c) Post-RMB reform period	0.9541 ***	0.0125	0.0279 ***	0.955
	(0.0121)	(0.0313)	(0.0108)	
(d) Subprime mortgage problem period	0.9735 ***	0.0180	−0.0037	0.978
	(0.0097)	(0.0143)	(0.0072)	
Indonesia yupiah	US dollar	euro	Japanese yen	Adj. R2
(a) Full samples	0.7818 ***	0.2940 **	0.2623 ***	0.098
	(0.0728)	(0.1491)	(0.0555)	
(b) Pre-RMB reform period	0.7432 ***	0.3079	0.3651 ***	0.079
	(0.1028)	(0.2468)	(0.0779)	
(c) Post-RMB reform period	0.6858 ***	0.4578 **	0.0086	0.265
	(0.0743)	(0.1933)	(0.0665)	
(d) Subprime mortgage problem period	1.0015 ***	0.0825	−0.0116	0.550
	(0.0608)	(0.0897)	(0.0453)	
South Korean won	US dollar	euro	Japanese yen	Adj. R2
(a) Full samples	0.8397 ***	0.4791 ***	0.0376	0.258
	(0.0376)	(0.0770)	(0.0286)	
(b) Pre-RMB reform period	0.9050 ***	0.0046	0.1230 ***	0.251
	(0.0473)	(0.1135)	(0.0358)	
(c) Post-RMB reform period	0.7430 ***	0.3056 ***	0.0900 ***	0.634
	(0.0371)	(0.0965)	(0.0332)	
(d) Subprime mortgage problem period	0.7370 ***	0.9513 ***	−0.1593 **	0.301
	(0.1028)	(0.1517)	(0.0766)	
Laos kip	US dollar	euro	Japanese yen	Adj. R2
(a) Full samples	0.9472 ***	0.0591 **	0.0085	0.821
	(0.0163)	(0.0299)	(0.0134)	
(b) Pre-RMB reform period	0.9821 ***	−0.0400	−0.0223	0.824
	(0.0298)	(0.0821)	(0.0281)	
(c) Post-RMB reform period	0.8770 ***	0.1989 **	0.0252	0.691
	(0.0356)	(0.0926)	(0.0319)	
(d) Subprime mortgage problem period	0.9632 ***	0.0590 *	0.0122	0.892
	(0.0229)	(0.0337)	(0.0170)	

Malaysian ringgit	US dollar	euro	Japanese yen	Adj. R2
(a) Full samples	0.8765 ***	0.2279 ***	0.0903 ***	0.545
	(0.0207)	(0.0425)	(0.0158)	
(b) Pre-RMB reform period	0.8930 ***	0.1658 **	0.1262 ***	0.498
	(0.0279)	(0.0670)	(0.0212)	
(c) Post-RMB reform period	0.8699 ***	0.2713 ***	0.0333	0.697
	(0.0356)	(0.0924)	(0.0318)	
(d) Subprime mortgage problem period	0.8419 ***	0.2583 ***	0.0033	0.760
	(0.0340)	(0.0502)	(0.0253)	
Myanmar kyat	US dollar	euro	Japanese yen	Adj. R2
(a) Full samples	0.9650 ***	0.0207	0.0026	0.913
	(0.0108)	(0.0199)	(0.0089)	
(b) Pre-RMB reform period	0.9837 ***	0.0008	−0.0211	0.939
	(0.0166)	(0.0457)	(0.0156)	
(c) Post-RMB reform period	0.8982 ***	0.1309 **	0.0277	0.861
	(0.0216)	(0.0562)	(0.0194)	
(d) Subprime mortgage problem period	0.9872 ***	0.0052	−0.0013	0.920
	(0.0194)	(0.0287)	(0.0145)	
Philippine peso	US dollar	euro	Japanese yen	Adj. R2
(a) Full samples	0.8707 ***	0.1925 ***	0.1024 ***	0.459
	(0.0246)	(0.0504)	(0.0187)	
(b) Pre-RMB reform period	0.8831 ***	0.0075	0.1459 ***	0.416
	(0.0324)	(0.0777)	(0.0246)	
(c) Post-RMB reform period	0.8711 ***	0.0508	0.0076	0.608
	(0.0407)	(0.1058)	(0.0364)	
(d) Subprime mortgage problem period	0.8637 ***	0.3821 ***	0.0282	0.635
	(0.0495)	(0.0731)	(0.0369)	
Singapore dollar	US dollar	euro	Japanese yen	Adj. R2
(a) Full samples	0.6811 ***	0.3048 ***	0.1761 ***	0.718
	(0.0126)	(0.0259)	(0.0096)	
(b) Pre-RMB reform period	0.6689 ***	0.1879 ***	0.2605 ***	0.722
	(0.0156)	(0.0375)	(0.0118)	
(c) Post-RMB reform period	0.6416 ***	0.3216 ***	0.2099 ***	0.848
	(0.0202)	(0.0525)	(0.0181)	
(d) Subprime mortgage problem period	0.7812 ***	0.2825 ***	−0.0904 ***	0.779
	(0.0287)	(0.0423)	(0.0214)	
Thai baht	US dollar	euro	Japanese yen	Adj. R2
(a) Full samples	0.7497 ***	0.2541 ***	0.1793 ***	0.375
	(0.0278)	(0.0570)	(0.0212)	
(b) Pre-RMB reform period	0.7115 ***	0.2854 ***	0.2333 ***	0.346
	(0.0356)	(0.0856)	(0.0270)	
(c) Post-RMB reform period	0.7418 ***	0.0868	0.1906 ***	0.403
	(0.0605)	(0.1574)	(0.0542)	
(d) Subprime mortgage problem period	0.9117 ***	0.1093	−0.0066	0.525
	(0.0589)	(0.0870)	(0.0439)	
Vietnamese dong	US dollar	euro	Japanese yen	Adj. R2
(a) Full samples	1.0015 ***	0.0040	−0.0003	0.979
	(0.0037)	(0.0074)	(0.0030)	
(b) Pre-RMB reform period	0.9976 ***	0.0000	0.0011	0.998
	(0.0016)	(0.0037)	(0.0013)	
(c) Post-RMB reform period	1.0001 ***	−0.0089	0.0032	0.994
	(0.0044)	(0.0113)	(0.0039)	
(d) Subprime mortgage problem period	1.0127 ***	0.0030	−0.0033	0.931
	(0.0183)	(0.0270)	(0.0136)	

*: significant level of 10%, **: significant level of 5%, ***: significant level of 1%

(a) Full samples: 1/3/2000-2/27/2009, (b) Pre-RMB reform period: 1/3/2000-7/20/2005, (c) Post-RMB reform period: 7/21/2005-8/7/2007, (d) Subprime mortgage problem period: 8/8/2007-2/27/2009

Standard deviations are reported between parentheses.

Table 2: Contribution of AMU Deviation Indicators (top 3 countries)

Nominal AMU DI		
(a) Full samples	Japan	62.4%
	China P.R.	30.3%
	South Korea	5.2%
(b) Pre-RMB reform period	China P.R.	49.0%
	Japan	47.2%
	Indonesia	4.1%
(c) Post-RMB reform period	Japan	83.8%
	South Korea	17.8%
	Indonesia	5.3%
(d) Subprime mortgage problem period	Japan	76.3%
	South Korea	14.5%
	China P.R.	9.0%
Real AMU DI		
(a) Full samples	Japan	58.4%
	China P.R.	27.0%
	South Korea	5.2%
(b) Pre-RMB reform period	China P.R.	49.4%
	Japan	35.5%
	Indonesia	3.5%
(c) Post-RMB reform period	Japan	100.8%
	South Korea	12.0%
	Indonesia	7.1%
(d) Subprime mortgage problem period	Japan	88.3%
	South Korea	4.1%
	China P.R.	3.7%

(a) Full samples: 1/3/2000-2/27/2009, (b) Pre-RMB reform period: 1/3/2000-7/20/2005, (c) Post-RMB reform period: 7/21/2005-8/7/2007, (d) Subprime mortgage problem period: 8/8/2007-2/27/2009

Source: Authors' calculations

Table 3: Estimation Results of Convergence among East Asian currencies

(a) Full samples (1/3/2000-2/27/2009)

Unit root test for averaged AMU DI						
Method	Data	Constant	Lag length	Obs.	Statistic	Prob.
ADF	Nominal	×	1	2388	−0.19	0.62
		○	1	2388	−1.51	0.53
	Real	×	0	105	0.21	0.75
		○	0	105	−0.99	0.76
Phillips-Perron	Nominal	×		2389	−0.29	0.58
		○		2389	−1.60	0.48
	Real	×		105	0.27	0.76
		○		105	−0.97	0.76
β −convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Statistic	Prob.
Levin, Lin and Chu	Nominal	×	0 to 3	31042	−0.87	0.19
		○	0 to 3	31042	1.58	0.94
	Real	×	0 to 1	1151	−1.17	0.12
		○	0 to 1	1151	0.32	0.62
Im, Pesaran and Shin	Nominal	○	0 to 3	31042	0.98	0.84
	Real	○	0 to 1	1151	0.36	0.64
σ −convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Statistic	Prob.
ADF	Nominal	×	0	2389	0.4	0.80
		○	0	2389	−0.42	0.90
	Real	×	0	100	0.94	0.91
		○	0	100	−0.73	0.83
Phillips-Perron	Nominal	×		2389	0.46	0.81
		○		2389	−0.35	0.91
	Real	×		105	0.67	0.86
		○		105	−0.97	0.76

(b) Pre-RMB reform period (1/3/2000-7/20/2005)

Unit root test for averaged AMU DI						
Method	Data	Constant	Lag length	Obs.	Statistic	Prob.
ADF	Nominal	×	0	1447	-1.59	0.11
		○	0	1447	-3.35 **	0.01
	Real	×	0	65	0.22	0.75
		○	0	65	-1.21	0.67
Phillips-Perron	Nominal	×		1447	-1.58	0.11
		○		1447	-3.43 **	0.01
	Real	×		65	0.22	0.75
		○		65	-1.34	0.61
β -convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Statistic	Prob.
Levin, Lin and Chu	Nominal	×	0 to 2	18804	-3.73 ***	0.00
		○	0 to 2	18804	-0.77	0.22
	Real	×	0 to 1	708	-2.32 **	0.01
		○	0 to 1	708	-1.38 *	0.08
Im, Pesaran and Shin	Nominal	○	0 to 2	18804	-1.24	0.11
	Real	○	0 to 1	708	-1.69 **	0.05
σ -convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Statistic	Prob.
ADF	Nominal	×	0	1447	-0.09	0.65
		○	0	1447	-0.69	0.85
	Real	×	0	65	0.34	0.78
		○	0	65	-0.84	0.80
Phillips-Perron	Nominal	×		1447	-0.15	0.63
		○		1447	-0.81	0.82
	Real	×		65	0.16	0.73
		○		65	-0.91	0.78

(c) Post-RMB reform period (7/21/2005-8/7/2007)

Unit root test for averaged AMU DI						
Method	Data	Constant	Lag length	Obs.	Statistic	Prob.
ADF	Nominal	×	1	532	1.41	0.96
		○	1	532	−1.00	0.76
	Real	×	0	24	3.24	1.00
		○	0	24	−0.39	0.90
Phillips-Perron	Nominal	×		533	1.45	0.96
		○		533	−1.14	0.70
	Real	×		24	3.52	1.00
		○		24	−0.27	0.92
β −convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Statistic	Prob.
Levin, Lin and Chu	Nominal	×	0 to 2	6917	0.64	0.74
		○	0 to 2	6917	−0.04	0.48
	Real	×	0 to 3	253	2.80	1.00
		○	0 to 2	256	0.03	0.51
Im, Pesaran and Shin	Nominal	○	0 to 2	6917	0.55	0.71
	Real	○	0 to 2	256	0.66	0.75
σ −convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Statistic	Prob.
ADF	Nominal	×	1	532	2.00	0.99
		○	1	532	0.61	0.99
	Real	×	0	24	2.62	1.00
		○	0	24	−1.26	0.63
Phillips-Perron	Nominal	×		533	2.57	1.00
		○		533	0.93	1.00
	Real	×		24	2.43	0.99
		○		24	−1.34	0.60

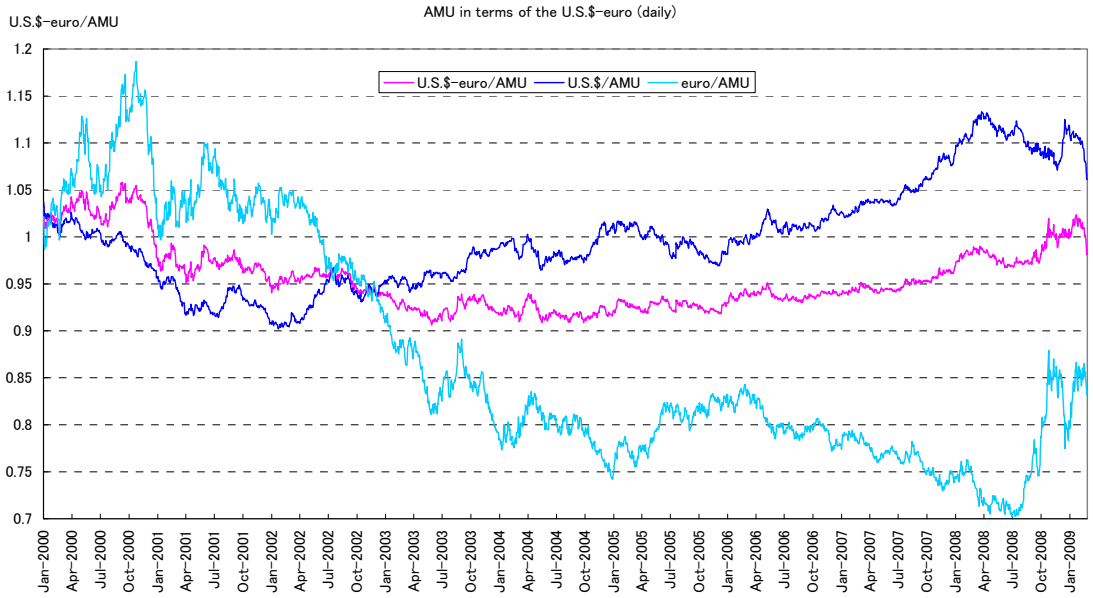
(d) Subprime mortgage problem period (8/8/2007-2/27/2009)

Unit root test for averaged AMU DI						
Method	Data	Constant	Lag length	Obs.	Statistic	Prob.
ADF	Nominal	×	0	407	−0.02	0.67
		○	0	407	−1.23	0.66
Phillips-Perron	Nominal	×		407	0.04	0.70
		○		407	−1.1	0.72
β −convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Statistic	Prob.
Levin, Lin and Chu	Nominal	×	0 to 3	5277	−0.48	0.32
		○	0 to 3	5277	2.05	0.98
	Real	×	0 to 1	153	0.44	0.67
		○	0 to 1	151	2.18	0.99
Im, Pesaran and Shin	Nominal	○	0 to 3	5277	3.21	1.00
	Real	○	0 to 1	151	2.12	0.98
σ −convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Statistic	Prob.
ADF	Nominal	×	0	407	−0.66	0.43
		○	0	407	−2.67 *	0.08
Phillips-Perron	Nominal	×		407	−0.66	0.43
		○		407	−2.68 *	0.08

*: significant level of 10%, **: significant level of 5%, ***: significant level of 1%

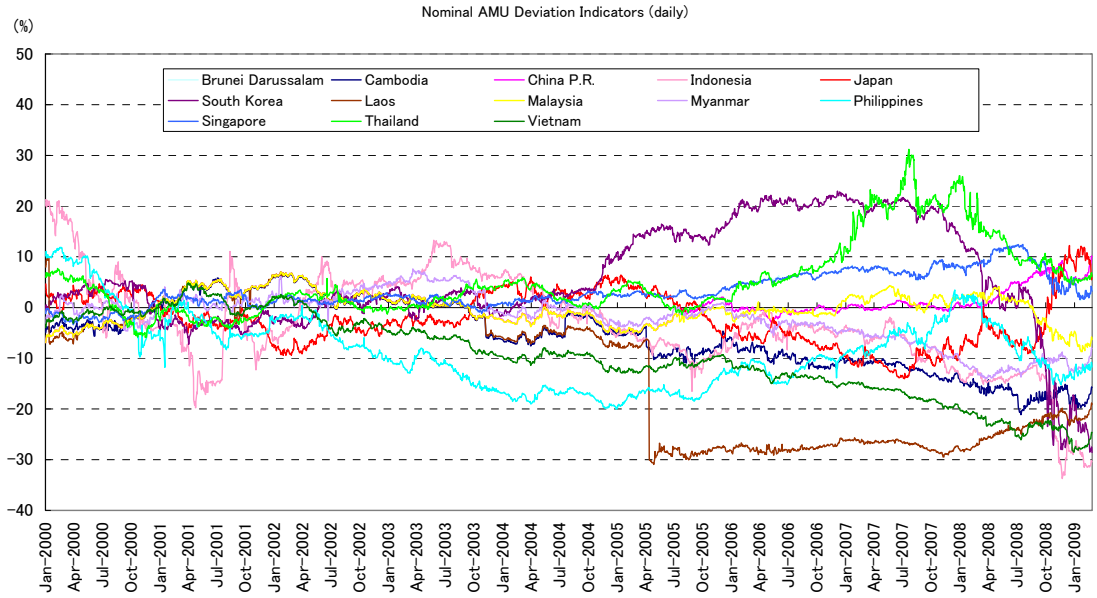
Source: Authors' calculations

Figure 1: Movement of East Asian currency



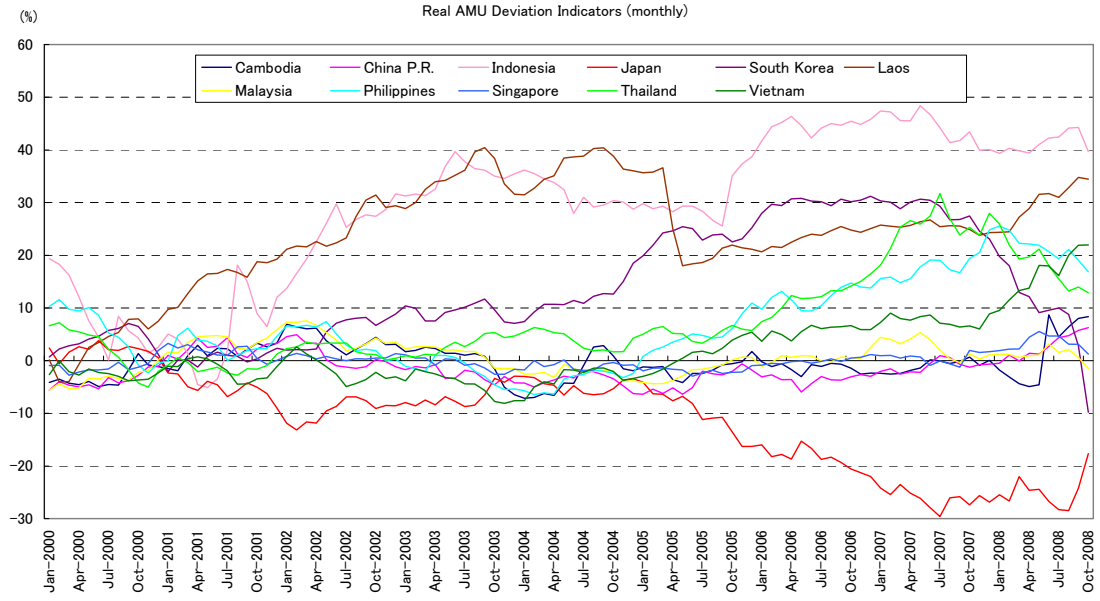
Source: http://www.rieti.go.jp/users/amu/en/index.html

Figure 2: Nominal AMU Deviation Indicators (daily)



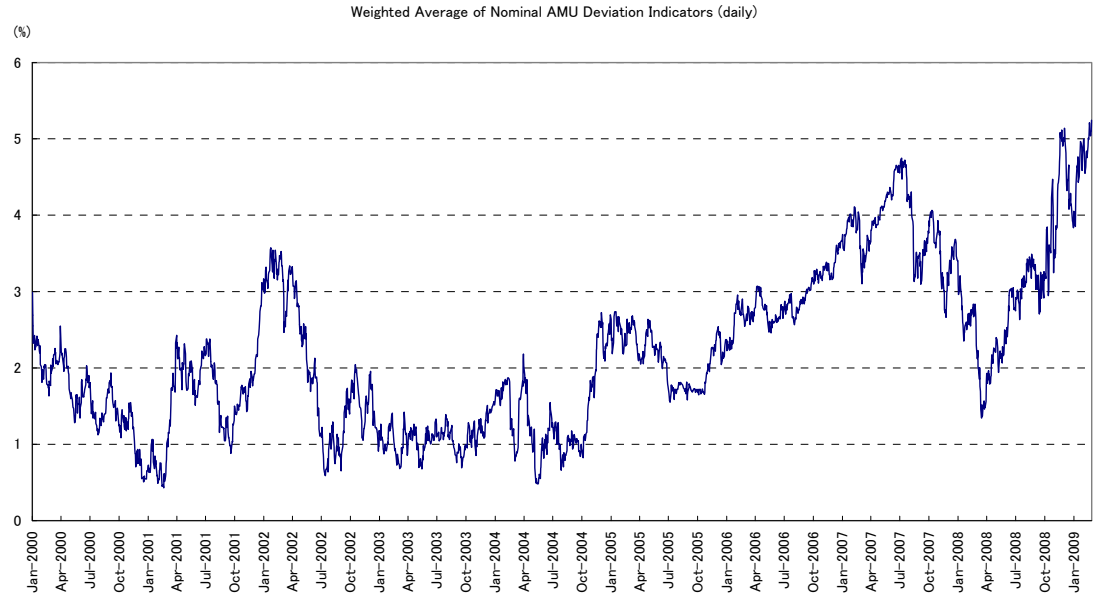
Source: http://www.rieti.go.jp/users/amu/en/index.html

Figure 3: Real AMU Deviation Indicators (monthly)



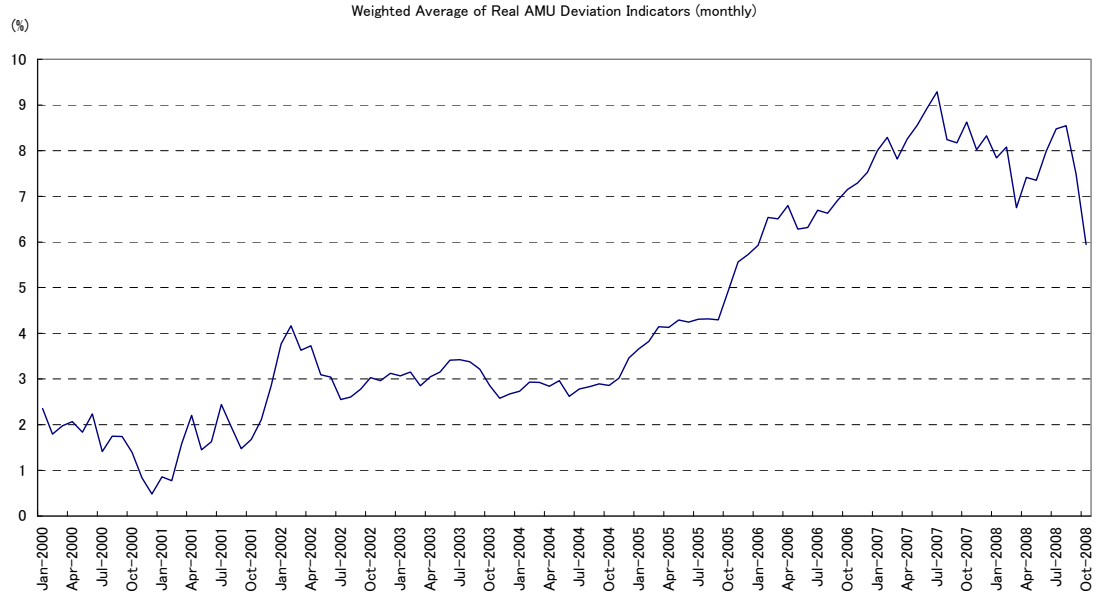
Source: http://www.rieti.go.jp/users/amu/en/index.html

Figure 4: Weighted Average of Nominal AMU Deviation Indicators



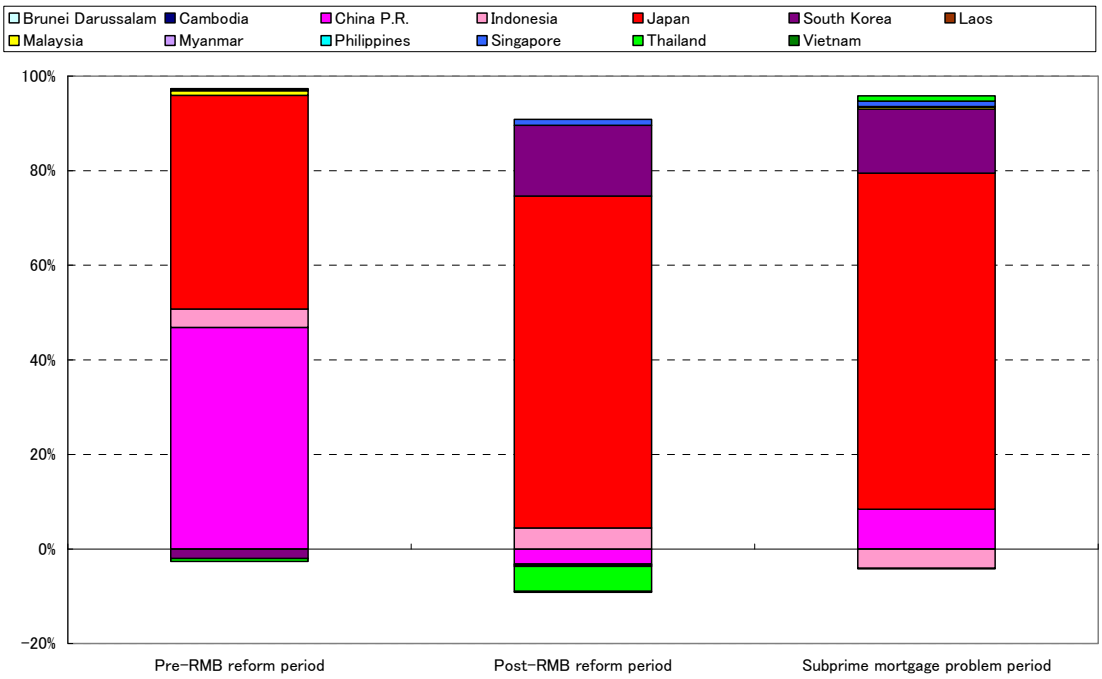
Source: Authors' calculations

Figure 5: Weighted Average of Real AMU Deviation Indicators



Source: Authors' calculations

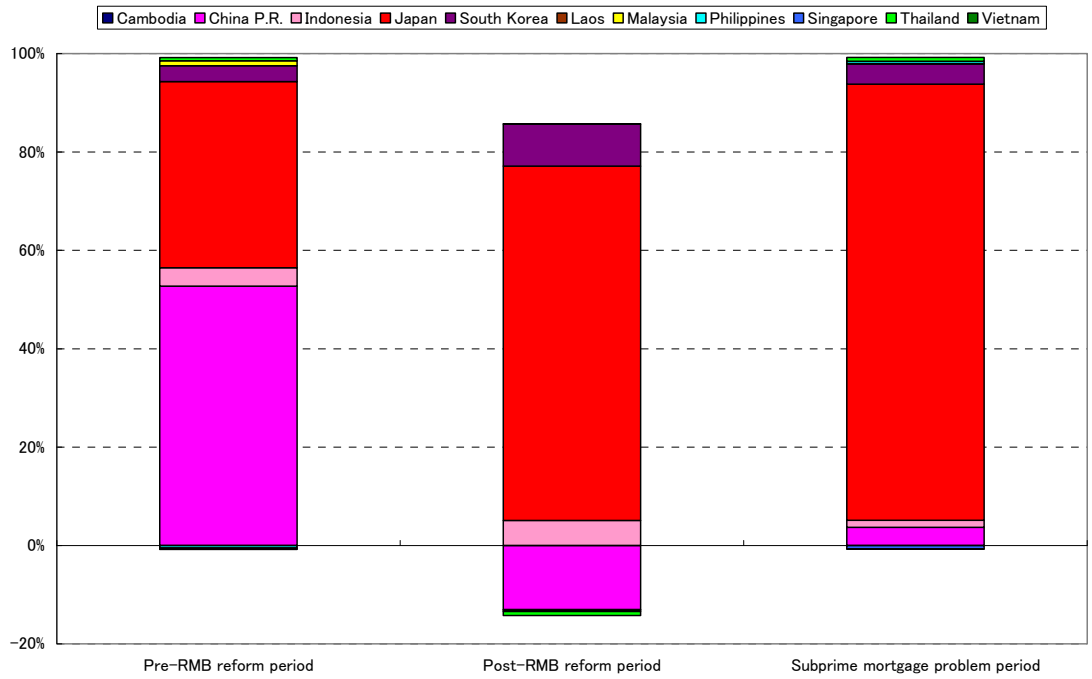
Figure 6: Contribution of Nominal AMU Deviation Indicators



Pre-RMB reform period: 1/3/2000-7/20/2005, Post-RMB reform period: 7/21/2005-8/7/2007, Subprime mortgage problem period: 8/8/2007-2/27/2009

Source: Authors' calculations

Figure 7: Contribution of Real AMU Deviation Indicators



Pre-RMB reform period: 1/3/2000-7/20/2005, Post-RMB reform period: 7/21/2005-8/7/2007, Subprime mortgage problem period: 8/8/2007-2/27/2009

Source: Authors' calculations