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Analysis on β and σ Convergences of East Asian Currencies*

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Abstract

This paper focuses on recent events which include the RMB reform in China and the global financial crisis to investigate statistically recent diverging trends among East Asian currencies. For the purpose, their weighted average value (Asian Monetary Unit: AMU) and their deviations (AMU Deviation Indicators) from benchmark levels are used to analyze both β and σ convergences of East Asian currencies. Our analytical results show that the monetary authority of China has still kept stabilizing the exchange rate of the Chinese yuan against only the US dollar even though it announced its adoption of a managed floating exchange rate system with reference to a currency. Analytical results on β and σ convergences show that deviations among the East Asian currencies have been diverging in recent years, especially after 2005. The widening deviations reflect not the RMB reform but recent international capital flows and the global financial crisis. In addition, it is important as its background that the monetary authorities of the countries 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.

An objective of this paper is to investigate recent diverging trend in East Asian currencies by using both β and σ convergence methods that were proposed by Adam *et al.* (2002). These methods enable us to understand whether East Asian currencies converge to their weighted average value or Asian Monetary Unit (AMU)[1]. 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.

Four recent events are likely to affect movements of East Asian currencies in the recent years. Firstly, it is said that active international capital flows such as yen carry trades brought about depreciation of the Japanese yen and appreciation of emerging economy country currencies such as the Korean won and the Thai baht during a period from 2005 to 2007. Secondly, the Chinese government made announcement of its exchange rate regime reform (RMB reform) that includes shifting a target of its exchange rate policy from the US dollar to a currency basket as well as revaluation of the Chinese yuan 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. Thirdly, the recent subprime mortgage problem, which happened in summer of 2007, might affect linkages among the East Asian currencies by changing capital flows in international financial markets. In addition, the Lehman shock that happened on September 15, 2008 has increased counterparty risks of financial institutions in inter-bank transaction, which escalate depreciation of the euro and the Sterling pound. It might affect movements in East Asian currencies which include appreciation of the Japanese yen and depreciation of the Korean won. We divide the whole sample period into five sub-sample periods based on the above events to investigate any changes in the movements and convergences

[1] The AMU is the weighted average of East Asian currencies and created by Ogawa and Shimizu (2005).

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. We analyze linkages of each of East Asian currencies with major international currencies during five sub-sample periods: Period 1 (January 3, 2000 to January 13, 2005), Period 2 (January 14, 2005 to July 20, 2005), Period 3 (July 21, 2005 to August 7, 2007), Period 4 (August 8, 2007 to September 14, 2008), and Period 5 (September 15, 2008 to February 27, 2009). We obtain that a currency basket is targeted in some countries while the monetary authorities of the other 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 weighted average value of East Asian currencies and deviations among them in recent years. A weighted average of the AMU Deviation Indicator is calculated in order to 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, both 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 Period 1. The fourth section 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

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 focuses on the above-mentioned events related with exchange rates during an extended sample period to early 2009. 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 five sub-sample

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

periods defined above. 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.

We follow the assumption in Frankel and Wei (1994) that the Swiss franc as a numeraire in the denomination of 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 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 been adopting 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 the entire analyzed period. Linkage with the US dollar remained at levels between 0.9104 and 1.0655. Coefficients on the euro and the yen were not statistically significant during the sample 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.

(3) Chinese yuan

On July 21, 2005, the Chinese government announced that 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 Period 1 and 0.9998 in Period 2. The linkage with the US dollar decreases to a level of 0.9541 in Period 3. Further, coefficients on the euro and the yen increase in Period 3 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. It means that the monetary authority of China has not yet implemented 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 Period 5. It reached the level of 1.0717 in this 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 Period 1. This implies that the Indonesian rupiah was influenced by factors other than the three major currencies.

(5) Korean won

Linkage of the Korean won with the US dollar decreased in Period 2. After the increasing linkages in two following sub-sample periods, the linkage with the US dollar decreased and took a level of 0.6409 in Period 5. In Period 3, linkage with the euro significantly increased. Further, linkage with the yen is statistically significant in first three sub-sample periods 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 0.9988. 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

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

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 1.0013 in Period 1 that is the highest level in all the three sub-sample periods. Linkage with the US dollar decreased to 0.7740 in Period 4.

(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 1.0005. 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 0.9429 and the highest in Period 1. The Philippine peso has some linkages with the euro and the yen in the last two and the first two sub-sample periods, 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 Period 5 and took a level of 0.8245.

(11) Thai baht

The Thai baht has strong linkage with the US dollar. The linkage with the euro is not significant except for Period 5. Further, the linkage with the Japanese yen is significant in the first three sub-sample periods.

(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 0.9880 and 1.0173 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 East Asian currencies have a variety of linkages with the

three major currencies. It implies the East Asian countries are adopting various exchange rate policies under the different exchange rate regimes. Further, we find interesting results that 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 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 most of 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 under the currency basket system.

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 common currency unit for East Asia that is a weighted average of the East Asian currencies where the East Asia includes the ASEAN10 + 3 (China, Japan, and South Korea). 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 shares are calculated as the average of the 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 recent movements in nominal exchange rates of AMU 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 countries with the United States 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 before May 2003 when the AMU depreciated about 10% compared with the benchmark years of 2000 and 2001. However, it reversed its trend to upward direction and returned to almost the same level as in the benchmark years (2000-2001) before October 2008. On one hand, the AMU was gradually appreciating against the US dollar before April 2008 though it has been depreciating since April

[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)

2008. It was gradually depreciating against the euro before July 2008 though it has rapidly appreciated since July 2008.

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 quickly since the end of 2007. The Thai baht was appreciating quickly from the end of 2006 to August 2007. It was overvalued by about 30% compared with the benchmark years. After then, the Thai baht has been depreciating quickly. 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 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:

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

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 was increasing since January 2005 and it reached the level of 4.7% in July 2007. After then, 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 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.

Contributions of each country's AMU Deviation Indicator to the weighted averaged AMU Deviation Indicator are reported in Figures 6 to 7. The contributions are calculated daily for the Nominal AMU Deviation Indicators and monthly for the Real AMU Deviation Indicators. Averages of contributions are calculated for each of the sub-sample periods as well as the full sample period as shown in Table 2.

Generally speaking, movements in the Japanese yen and the Chinese yuan have contributed to movements in the weighted average of the AMU Deviation Indicators before the RMB reform. After the RMB reform, 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 Period 5 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 after the RMB reform, as shown in Figures 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- and σ-convergences 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 use the methods of β- and σ-convergences to investigate statistically whether

deviations among the East Asian currencies are widening. The following equation is estimated in order to analyze whether the AMU Deviation Indicators converge among the East Asian currencies during the sample period and how fast they are converging if they are converging.

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

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 the 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 the 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- 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. We propose both notions of convergence to assess convergence among East Asian currencies as the two indicators have different informational contents. Especially, we can have a situation where currencies converge in terms of σ-convergence while they diverge in terms of β-convergence at the same time because the decrease in the cross-sectional variance among AMU Deviation Indicators does not necessarily imply mean reversion or convergence of AMU Deviation Indicators to its benchmark level. Further, β-convergence does not imply σ-convergence since mean reversion does not imply that the cross sectional variance decreases over time. In fact, the two tests generated inconsistent results in some of our estimations.

We focus on effect of the RMB reform, international capital flows such as yen carry trades, and the global financial crisis on divergence among the East Asian currencies to divide the full sample period (January 3, 2000 to February 27, 2009) into the five sub-sample periods like the above analysis on linkages of each of East Asian currencies with major international currencies. The five sub-sample period include Period 1 (January 3, 2000 to January 13, 2005), Period 2 (January 14, 2005 to July 20, 2005), Period 3 (July 21, 2005 to August 7, 2007), Period 4 (August 8, 2007 to September 14, 2008), and Period 5 (September 15, 2008 to February 27, 2009).

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. 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 with the full samples (January 3, 2000 to February 27, 2009). Both the LLC and IPS tests have a result that they have no β-convergence among the East Asian currencies. Regarding σ-convergence, 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 shows that, in Period 1, both the LLC test has 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, in Periods 2 to 5, we cannot reject the unit root hypothesis in the ADF and PP tests for both the weighted average of AMU Deviation Indicators and σ-convergence while both of the LLC and IPS tests have a result that they have β-convergence among the East Asian currencies in few of the estimations. This is because active international capital flows such as yen

carry trades made the depreciation of the yen and appreciations of the Korean won and the baht, and pushed the divergence among the sample currencies. Further this diverging trend is almost stable after the subprime mortgage problem happened in summer 2007.

The empirical results mean that East Asian currencies do not converge at least after early 2005 although it is found that they had β-convergence during the period from 2000 to early 2005 in some of the estimations.

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 kept targeting stabilization of the Chinese yuan against the US dollar only. 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 should target stabilization of their home currency against not only 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 United States. 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 Chiang Mai Initiative, a network of bilateral and multilateral swap arrangements was established for managing currency crises in ASEAN+3 countries. In addition, the 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 United States and Europe.

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 unit should be created in the future.

5. Conclusion

This paper used the AMU Deviation Indicators of East Asian currencies to investigate divergence among them in the recent years. The divergence among the East Asian currencies reflects in a variety of exchange rate systems among the East Asian countries. The IMF classification tells us that the monetary authorities of East Asian countries are adopting various exchange rate systems.

The two corner solutions for exchange rate systems and intermediate exchange rate systems are found in East Asia. Exchange rate systems in East Asia have a tendency toward greater flexibility following the Asian Currency Crisis. For example the Chinese government's announcement to change from a dollar-peg system to a managed floating exchange rate system with reference to a currency basket. The monetary authority of Malaysia followed the China's announcement immediately after the announcement.

Our 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 in summer 2007. The monetary authority of Singapore appears to have adopted a currency basket which includes the US dollar, the euro, and 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 analytical results show that deviations among the East Asian currencies have been widening as shown by their AMU Deviation Indicators and the weighted average of the AMU Deviation Indicators. The analytical results on β and σ convergences show that the East Asian currencies have been diverging after early 2005 although they had β-convergence during the period from 2000 to early 2005 in some of the tests. East Asian currencies do not converge at least even after the RMB reform. It reflected the fact that the monetary authority of China has substantially no change into a managed floating system with reference to a currency basket under the RMB reform. On one hand, active international capital flows such as yen carry trades that seemed to start early 2005 as well as the recent global financial crisis have had diverging effects on the East Asian currencies.

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

Brunei dollar	US dollar	euro	Japanese yen	Adj. R2
Full samples	0.7003 ***	0.2852 ***	0.0817 ***	0.823
	(0.0104)	(0.0199)	(0.0086)	
Period 1	0.7136 ***	0.0762 ***	0.1785 ***	0.872
	(0.0127)	(0.0283)	(0.0108)	
Period 2	0.5443 ***	0.0265	0.2636 ***	0.865
	(0.0353)	(0.0966)	(0.0375)	
Period 3	0.6255 ***	0.3649 ***	0.1356 ***	0.807
	(0.0218)	(0.0566)	(0.0195)	
Period 4	0.6590 ***	0.4337 ***	−0.0593 **	0.811
	(0.0308)	(0.0512)	(0.0249)	
Period 5	0.7056 ***	0.3506 ***	−0.0758 **	0.824
	(0.0426)	(0.0575)	(0.0299)	
Cambodia riel	US dollar	euro	Japanese yen	Adj. R2
Full samples	0.9714 ***	−0.0067	0.0221	0.713
	(0.0226)	(0.0415)	(0.0186)	
Period 1	0.9699 ***	0.0768	−0.0258	0.842
	(0.0333)	(0.0917)	(0.0305)	
Period 2	0.9949 ***	0.2031	−0.0226	0.739
	(0.0761)	(0.2080)	(0.0809)	
Period 3	0.9104 ***	0.0191	0.0367	0.628
	(0.0414)	(0.1075)	(0.0371)	
Period 4	1.0655 ***	−0.0416	0.0022	0.641
	(0.0633)	(0.1053)	(0.0512)	
Period 5	0.9492 ***	−0.0299	0.0517	0.741
	(0.0731)	(0.0987)	(0.0514)	
Chinese yuan	US dollar	euro	Japanese yen	Adj. R2
Full samples	0.9864 ***	0.0079	0.0026	0.988
	(0.0030)	(0.0058)	(0.0025)	
Period 1	1.0002 ***	−0.0002	−0.0001	1.000
	(0.0002)	(0.0004)	(0.0001)	
Period 2	0.9998 ***	0.0001	0.0002	1.000
	(0.0002)	(0.0006)	(0.0002)	
Period 3	0.9541 ***	0.0125	0.0279 ***	0.955
	(0.0121)	(0.0313)	(0.0108)	
Period 4	0.9652 ***	−0.0128	0.0030	0.963
	(0.0151)	(0.0251)	(0.0122)	
Period 5	0.9882 ***	0.0320 *	−0.0099	0.990
	(0.0122)	(0.0165)	(0.0086)	
Indonesia yupiah	US dollar	euro	Japanese yen	Adj. R2
Full samples	0.9256 ***	0.0993	0.0664 **	0.414
	(0.0325)	(0.0623)	(0.0269)	
Period 1	0.9413 ***	0.0010	0.1227 ***	0.393
	(0.0489)	(0.1094)	(0.0419)	
Period 2	0.8311 ***	0.1105	0.0885	0.722
	(0.0701)	(0.1916)	(0.0745)	
Period 3	0.6858 ***	0.4578 **	0.0086	0.265
	(0.0743)	(0.1933)	(0.0665)	
Period 4	0.8907 ***	0.2747 ***	−0.0038	0.809
	(0.0382)	(0.0635)	(0.0309)	
Period 5	1.0717 ***	−0.0193	−0.0278	0.453
	(0.1418)	(0.1915)	(0.0997)	

South Korean won	US dollar	euro	Japanese yen	Adj. R2
Full samples	0.7843 ***	0.5669 ***	0.0529 **	0.434
	(0.0293)	(0.0563)	(0.0242)	
Period 1	0.8037 ***	−0.0083	0.2361 ***	0.635
	(0.0287)	(0.0643)	(0.0246)	
Period 2	0.5128 ***	0.0285	0.1963 *	0.478
	(0.0826)	(0.2258)	(0.0878)	
Period 3	0.7430 ***	0.3056 ***	0.0900 ***	0.634
	(0.0371)	(0.0965)	(0.0332)	
Period 4	0.9392 ***	0.5535 ***	−0.0802	0.576
	(0.0761)	(0.1266)	(0.0615)	
Period 5	0.6409 ***	1.1006 ***	−0.1729	0.200
	(0.2341)	(0.3161)	(0.1645)	
Laos kip	US dollar	euro	Japanese yen	Adj. R2
Full samples	0.9472 ***	0.0591 **	0.0085	0.821
	(0.0163)	(0.0299)	(0.0134)	
Period 1	0.9749 ***	−0.0148	−0.0248	0.920
	(0.0225)	(0.0619)	(0.0206)	
Period 2	0.9988 ***	−0.1126	−0.0080	0.603
	(0.0996)	(0.2721)	(0.1056)	
Period 3	0.8770 ***	0.1989 **	0.0252	0.691
	(0.0356)	(0.0926)	(0.0319)	
Period 4	0.9597 ***	0.0767	0.0043	0.869
	(0.0308)	(0.0512)	(0.0249)	
Period 5	0.9629 ***	0.0496	0.0162	0.908
	(0.0393)	(0.0530)	(0.0276)	
Malaysian ringgit	US dollar	euro	Japanese yen	Adj. R2
Full samples	0.9431 ***	0.1397 ***	0.0003	0.880
	(0.0099)	(0.0190)	(0.0082)	
Period 1	1.0013 ***	−0.0010	−0.0005	0.999
	(0.0011)	(0.0026)	(0.0010)	
Period 2	0.9997 ***	−0.0009	0.0005	1.000
	(0.0004)	(0.0010)	(0.0004)	
Period 3	0.8699 ***	0.2713 ***	0.0333	0.697
	(0.0356)	(0.0924)	(0.0318)	
Period 4	0.7740 ***	0.4411 ***	0.1090 ***	0.698
	(0.0513)	(0.0854)	(0.0415)	
Period 5	0.8805 ***	0.1501 **	−0.0514	0.845
	(0.0465)	(0.0628)	(0.0327)	
Myanmar kyat	US dollar	euro	Japanese yen	Adj. R2
Full samples	0.9650 ***	0.0207	0.0026	0.913
	(0.0108)	(0.0199)	(0.0089)	
Period 1	0.9765 ***	−0.0082	−0.0163	0.931
	(0.0209)	(0.0575)	(0.0191)	
Period 2	1.0006 ***	0.0304	−0.0322	0.964
	(0.0241)	(0.0658)	(0.0256)	
Period 3	0.8982 ***	0.1309 **	0.0277	0.861
	(0.0216)	(0.0562)	(0.0194)	
Period 4	0.9922 ***	0.0265	−0.0172	0.926
	(0.0226)	(0.0376)	(0.0183)	
Period 5	0.9774 ***	−0.0049	0.0083	0.914
	(0.0378)	(0.0510)	(0.0266)	

Philippine peso	US dollar	euro	Japanese yen	Adj. R2
Full samples	0.9096 ***	0.1798 ***	0.0399 **	0.607
	(0.0215)	(0.0413)	(0.0178)	
Period 1	0.9429 ***	−0.0663	0.0672 **	0.591
	(0.0312)	(0.0698)	(0.0267)	
Period 2	0.7872 ***	0.1783	0.1931 ***	0.809
	(0.0567)	(0.1548)	(0.0602)	
Period 3	0.8711 ***	0.0508	0.0076	0.608
	(0.0407)	(0.1058)	(0.0364)	
Period 4	0.8938 ***	0.4046 ***	0.0849	0.526
	(0.0811)	(0.1349)	(0.0656)	
Period 5	0.8381 ***	0.3536 ***	0.0090	0.805
	(0.0566)	(0.0765)	(0.0398)	
Singapore dollar	US dollar	euro	Japanese yen	Adj. R2
Full samples	0.7156 ***	0.2571 ***	0.1142 ***	0.823
	(0.0108)	(0.0207)	(0.0089)	
Period 1	0.6900 ***	0.0778 ***	0.2346 ***	0.888
	(0.0121)	(0.0271)	(0.0104)	
Period 2	0.5056 ***	0.0705	0.3694 ***	0.882
	(0.0346)	(0.0947)	(0.0368)	
Period 3	0.6416 ***	0.3216 ***	0.2099 ***	0.848
	(0.0202)	(0.0525)	(0.0181)	
Period 4	0.7362 ***	0.2807 ***	−0.0773 ***	0.800
	(0.0323)	(0.0537)	(0.0261)	
Period 5	0.8246 ***	0.2853 ***	−0.1058 ***	0.763
	(0.0565)	(0.0763)	(0.0397)	
Thai baht	US dollar	euro	Japanese yen	Adj. R2
Full samples	0.8045 ***	0.1375 ***	0.1234 ***	0.614
	(0.0201)	(0.0386)	(0.0166)	
Period 1	0.7668 ***	0.0672	0.1971 ***	0.762
	(0.0198)	(0.0444)	(0.0170)	
Period 2	0.6747 ***	0.0123	0.2506 ***	0.827
	(0.0476)	(0.1301)	(0.0506)	
Period 3	0.7418 ***	0.0868	0.1906 ***	0.403
	(0.0605)	(0.1574)	(0.0542)	
Period 4	0.9449 ***	0.1084	−0.0067	0.348
	(0.1065)	(0.1771)	(0.0861)	
Period 5	0.8812 ***	0.1058 **	0.0003	0.931
	(0.0307)	(0.0415)	(0.0216)	
Vietnamese dong	US dollar	euro	Japanese yen	Adj. R2
Full samples	1.0018 ***	0.0043	−0.0005	0.978
	(0.0042)	(0.0081)	(0.0035)	
Period 1	0.9980 ***	0.0008	0.0008	0.998
	(0.0019)	(0.0042)	(0.0016)	
Period 2	0.9880 ***	0.0005	0.0081	0.995
	(0.0089)	(0.0244)	(0.0095)	
Period 3	1.0001 ***	−0.0089	0.0032	0.994
	(0.0044)	(0.0113)	(0.0039)	
Period 4	1.0173 ***	0.0188	−0.0067	0.916
	(0.0248)	(0.0412)	(0.0200)	
Period 5	1.0064 ***	−0.0091	0.0003	0.943
	(0.0311)	(0.0420)	(0.0218)	

*: significant level of 10%, **: significant level of 5%, ***: significant level of 1%. Standard deviations are reported between parentheses.

Full samples: 1/3/2000-2/27/2009, Period 1: 1/3/2000-1/13/2005, Period 2: 1/14/2005-7/20/2005, Period 3: 7/21/2005-8/7/2007, Period 4: 8/8/2007-9/14/2008, Period 5: 9/15/2008-2/27/2009.

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

Nominal AMU DI			Real AMU DI		
Full samples	Japan	60.4%	Full samples	Japan	58.4%
	China P.R.	30.3%		China P.R.	27.0%
	South Korea	5.2%		South Korea	5.2%
Period 1	China P.R.	49.8%	Period 1	Japan	70.0%
	Japan	41.8%		China P.R.	23.3%
	Indonesia	4.1%		South Korea	2.5%
Period 2	Japan	99.7%	Period 2	China P.R.	284.8%
	China P.R.	41.3%		Indonesia	29.3%
	Indonesia	4.0%		South Korea	8.1%
Period 3	Japan	83.8%	Period 3	Japan	100.8%
	South Korea	17.8%		South Korea	12.0%
	Indonesia	5.3%		Indonesia	7.1%
Period 4	Japan	74.2%	Period 4	Japan	86.6%
	China P.R.	18.4%		South Korea	5.7%
	South Korea	5.3%		China P.R.	5.2%
Period 5	Japan	81.3%	Period 5	Japan	99.4%
	South Korea	36.3%		Indonesia	2.8%
	Thailand	0.7%		Philippines	0.2%

Full samples: 1/3/2000-2/27/2009, Period 1: 1/3/2000-1/13/2005, Period 2: 1/14/2005-7/20/2005, Period 3: 7/21/2005-8/7/2007, Period 4: 8/8/2007-9/14/2008, Period 5: 9/15/2008-2/27/2009.

Source: Authors' calculations

Table 3: Estimation Results of Convergence among East Asian currencies

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

Unit root test for averaged AMU DI						
Method	Data	Constant	Lag length	Obs.	Test 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.	Test 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.	Test 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

Period 1 (1/3/2000-1/13/2005)

Unit root test for averaged AMU DI						
Method	Data	Constant	Lag length	Obs.	Test statistic	Prob.
ADF	Nominal	×	0	1313	−1.28	0.18
		○	0	1313	−3.1 **	0.03
	Real	×	0	59	−0.14	0.63
		○	0	59	−1.65	0.45
Phillips-Perron	Nominal	×		1313	−1.28	0.19
		○		1313	−3.18 **	0.02
	Real	×		59	−0.14	0.63
		○		59	−1.73	0.41
β −convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Test statistic	Prob.
Levin, Lin and Chu	Nominal	×	0 to 2	17062	−3.50 ***	0.00
		○	0 to 2	17062	−0.09	0.46
	Real	×	0 to 1	645	−1.23	0.11
		○	0 to 1	645	−1.69 **	0.05
Im, Pesaran and Shin	Nominal	○	0 to 2	17062	−1.17	0.12
	Real	○	0 to 1	645	−1.19	0.12
σ −convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Test statistic	Prob.
ADF	Nominal	×	0	1313	−1.11	0.24
		○	0	1313	−2.15	0.23
	Real	×	0	59	1.39	0.96
		○	0	59	−0.20	0.93
Phillips-Perron	Nominal	×		1313	−1.06	0.26
		○		1313	−2.07	0.26
	Real	×		59	0.90	0.90
		○		59	−0.36	0.91

Period 2 (1/14/2005-7/20/2005)

Unit root test for averaged AMU DI						
Method	Data	Constant	Lag length	Obs.	Test statistic	Prob.
ADF	Nominal	×	0	133	−1.32	0.17
		○	0	133	−1.30	0.63
Phillips-Perron	Nominal	×		133	−1.36	0.16
		○		133	−1.33	0.62
β −convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Test statistic	Prob.
Levin, Lin and Chu	Nominal	×	0	1729	−2.34 ***	0.01
		○	0	1729	0.88	0.81
Im, Pesaran and Shin	Nominal	○	0	1729	0.89	0.81
σ −convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Test statistic	Prob.
ADF	Nominal	×	0	133	−0.29	0.77
		○	0	133	−1.32	0.62
Phillips-Perron	Nominal	×		133	0.25	0.76
		○		133	−1.39	0.58

Period 3 (7/21/2005-8/7/2007)

Unit root test for averaged AMU DI						
Method	Data	Constant	Lag length	Obs.	Test 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.	Test 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.	Test 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

Period 4 (8/8/2007-9/14/2008)

Unit root test for averaged AMU DI						
Method	Data	Constant	Lag length	Obs.	Test statistic	Prob.
ADF	Nominal	×	0	287	−1.01	0.28
		○	0	287	−2.30	0.17
Phillips-Perron	Nominal	×		287	−1.01	0.28
		○		287	−2.33	0.16
β −convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Test statistic	Prob.
Levin, Lin and Chu	Nominal	×	0 to 2	3720	−0.24	0.40
		○	0 to 1	3722	1.13	0.87
	Real	×	0 to 1	130	0.52	0.70
		○	0 to 2	123	−1.29 *	0.10
Im, Pesaran and Shin	Nominal	○	0 to 1	3722	2.07	0.98
	Real	○	0 to 2	123	0.59	0.72
σ −convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Test statistic	Prob.
ADF	Nominal	×	0	287	−1.47	0.13
		○	0	287	−1.71	0.43
Phillips-Perron	Nominal	×		287	−1.50	0.12
		○		287	−1.78	0.39

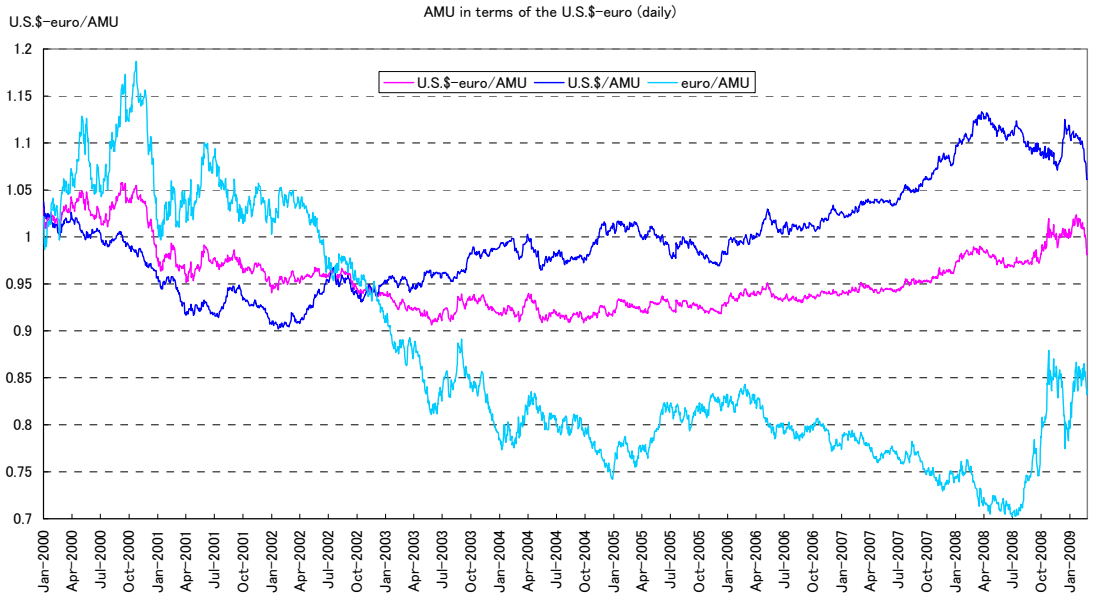
Period 5 (9/15/2008-2/27/2009)

Unit root test for averaged AMU DI						
Method	Data	Constant	Lag length	Obs.	Test statistic	Prob.
ADF	Nominal	×	0	119	0.81	0.89
		○	0	119	−2.03	0.27
Phillips-Perron	Nominal	×		119	1.17	0.94
		○		119	−1.92	0.32
β −convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Test statistic	Prob.
Levin, Lin and Chu	Nominal	×	0 to 2	1544	−0.65	0.26
		○	0 to 1	1545	−1.93 **	0.03
Im, Pesaran and Shin	Nominal	○	0 to 1	1545	−1.32 *	0.09
σ −convergence test for AMU DI						
Method	Data	Constant	Lag length	Obs.	Test statistic	Prob.
ADF	Nominal	×	0	119	0.81	0.89
		○	0	119	−1.69	0.43
Phillips-Perron	Nominal	×		119	1.03	0.92
		○		119	−1.64	0.46

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

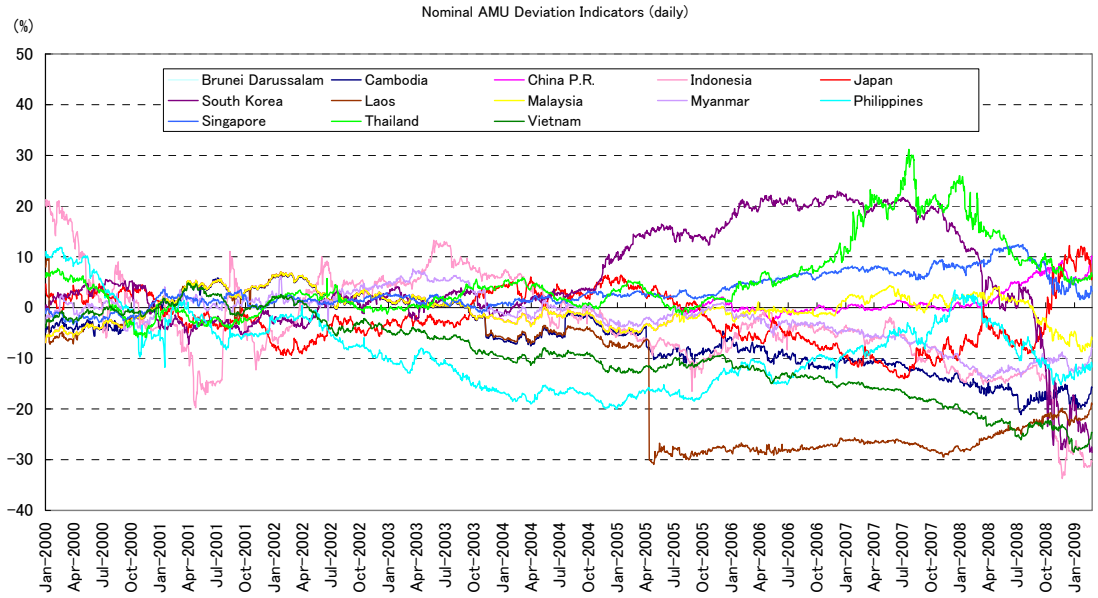
Source: Authors' calculations

Figure 1: Movement of East Asian currency



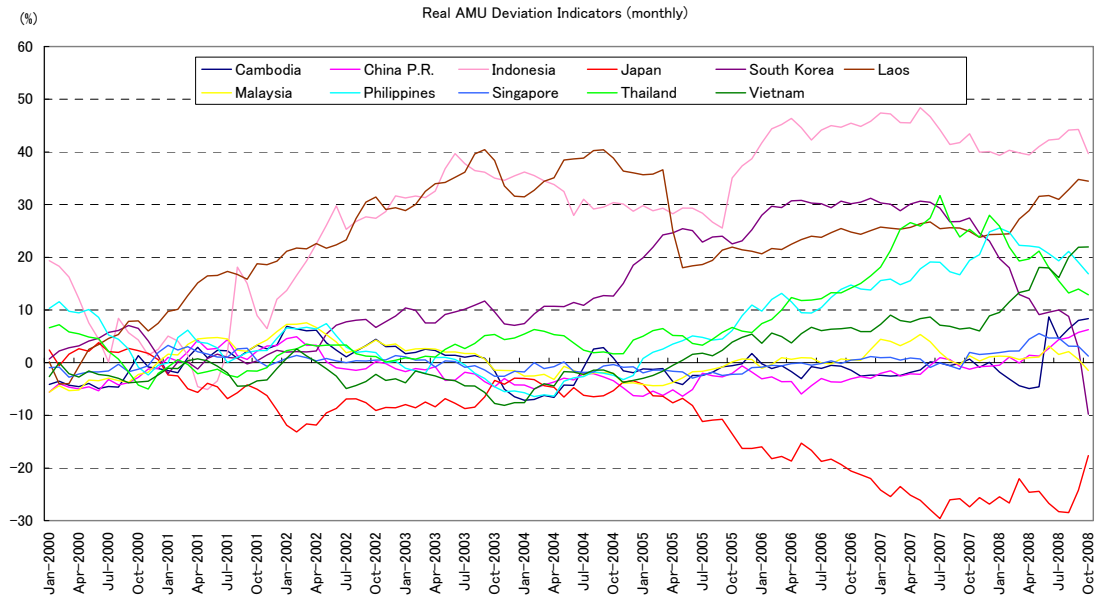
Source: http://www.rieti.go.jp/users/amu/en/index.html

Figure 2: Nominal AMU Deviation Indicators (daily)



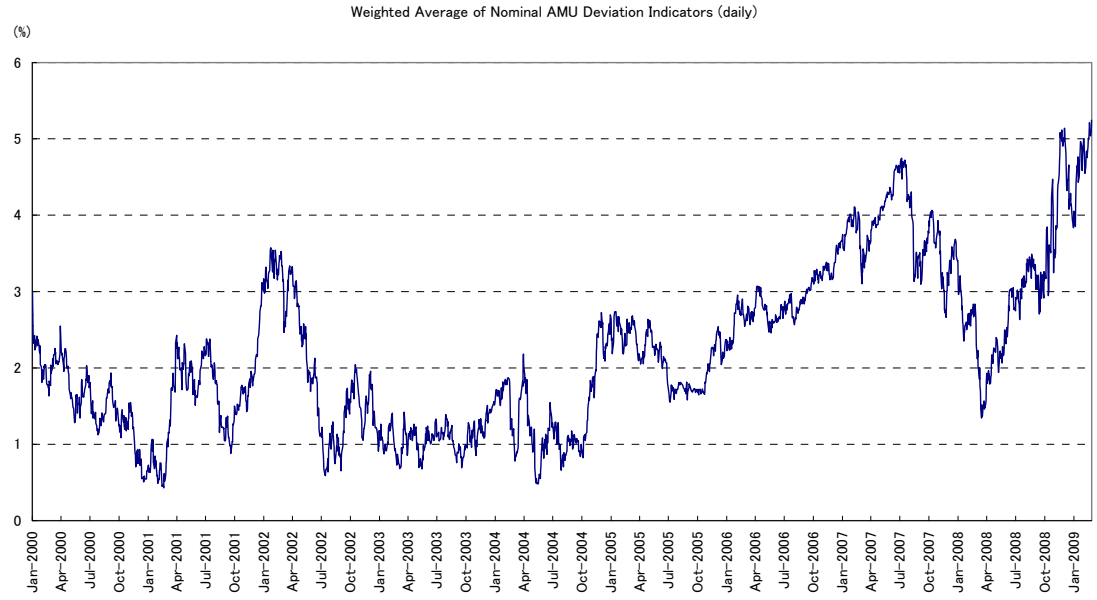
Source: http://www.rieti.go.jp/users/amu/en/index.html

Figure 3: Real AMU Deviation Indicators (monthly)



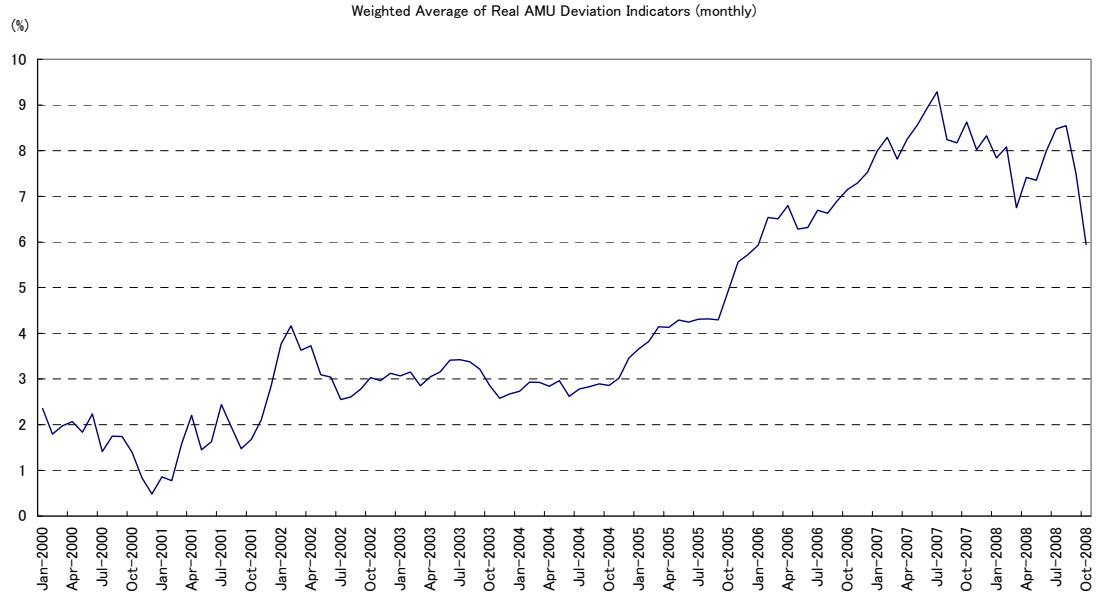
Source: http://www.rieti.go.jp/users/amu/en/index.html

Figure 4: Weighted Average of Nominal AMU Deviation Indicators



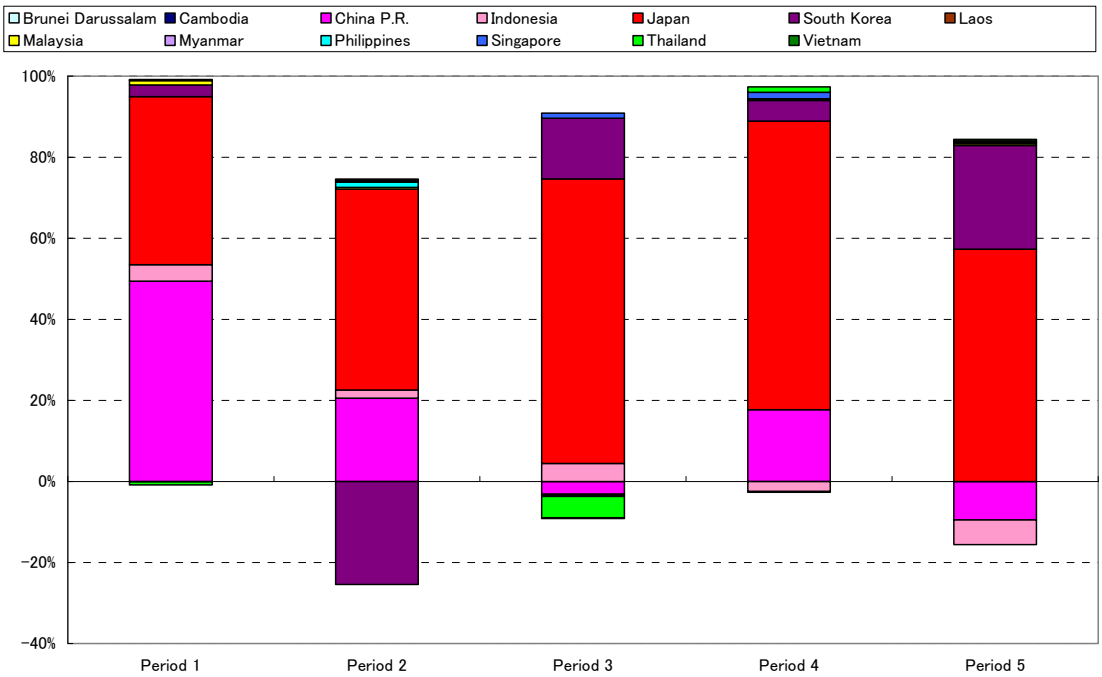
Source: Authors' calculations

Figure 5: Weighted Average of Real AMU Deviation Indicators



Source: Authors' calculations

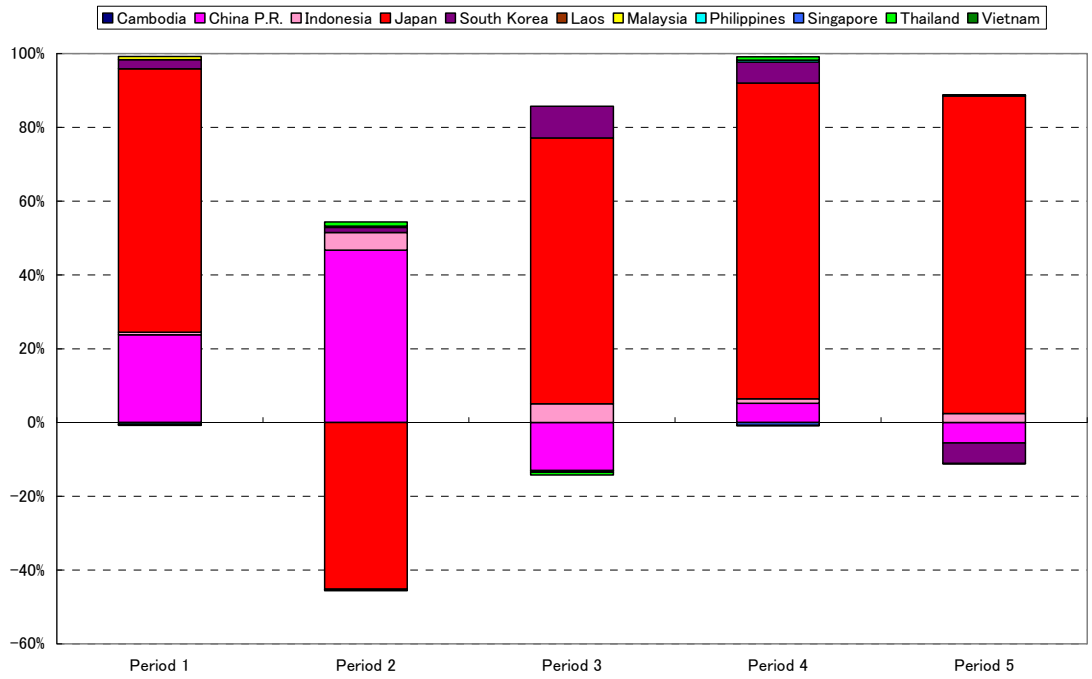
Figure 6: Contribution of Nominal AMU Deviation Indicators



Period 1: 1/3/2000-1/13/2005, Period 2: 1/14/2005-7/20/2005, Period 3: 7/21/2005-8/7/2007, Period 4: 8/8/2007-9/14/2008, Period 5: 9/15/2008-2/27/2009.

Source: Authors' calculations

Figure 7: Contribution of Real AMU Deviation Indicators



Period 1: 1/3/2000-1/13/2005, Period 2: 1/14/2005-7/20/2005, Period 3: 7/21/2005-8/7/2007, Period 4: 8/8/2007-9/14/2008, Period 5: 9/15/2008-2/27/2009.

Source: Authors' calculations