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# Analysis of the Stationarity of East Asian Currencies Using Unit Root Test and Cointegration Test*

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**ABSTRACT**

This paper investigates the stationarity of East Asian currencies (ASEAN 6) by using a unit root test and cointegration test. We examine whether the Asian monetary unit (AMU) deviation indicators adjusted by the Balassa–Samuelson effect of ASEAN 6 are stationary over the short term by carrying out a unit root test. We also assess whether cointegration relationships exist over the long term by carrying out a cointegration test. Based on an empirical analysis of 57 combinations, we cannot find any combinations show a significant result. Based on our results, it is clear that exchange rate fluctuations among the East Asian currencies respond to each other asymmetrically and that the issue of exchange rate misalignment needs to be dealt with immediately.

**Keywords:** Unit Root Test, Cointegration Test, Exchange Rate Misalignment, Intra-Regional Exchange Rate Surveillance

**JEL classification codes:** F31, F33, F36

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## 1. Introduction

In 1997, a number of East Asian countries experienced a serious currency crisis. The crisis was blamed on the *de facto* dollar peg exchange rate regime and on double mismatches in currency and the redemption periods. In the aftermath of the Asian currency crisis, the monetary authorities of most East Asian countries came to perceive the importance of establishing an intra-regional exchange rate surveillance system in the East Asian area. In order to realize the establishment of this surveillance system, the Asian monetary unit (AMU), AMU deviation indicator, and AMU deviation indicator adjusted by the Balassa–Samuelson effect (hereafter referred to as the adjusted AMU deviation indicator) have been proposed, along with an intra-regional surveillance process based on these indicators. However, the implications of surveillance will vary depending on whether exchange rate misalignments have a tendency to converge over the long run.

More specifically, based on the need to establish a system for monitoring intra-regional exchange rates and their fluctuations, some policymakers and academics have suggested the introduction of a common basket system in the East Asian area (i.e., Kuroda & Kawai, 2003; Ogawa, 2004; Williamson, 2000). Among the various approaches to simulating a common currency basket, Ogawa and Shimizu (2005, 2006, 2010, 2011) thought that the AMU and the AMU deviation indicator are useful for enhancing intra-regional monetary cooperation. These indicators are expected to strengthen the abilities of a surveillance system, especially in the early detection of exchange rate misalignment. Furthermore, considering the high productivity growth rate in tradable goods sectors and transformations in foreign exchange regimes in some East Asian countries, Ogawa and Wang (2012) calculated the adjusted AMU deviation indicator. It can also identify in what currencies intra-regional exchange rate misalignments occur and how serious they are. However, if exchange rate misalignments occurring in the East Asian currencies involve linear relationships, this means that the currencies' exchange rate fluctuations follow similar trends over the long run and that exchange rate misalignments occurring in the East Asian countries are temporary episodes. Given this, it is necessary to clarify the exchange rate relationships in East Asian currencies when we focus on intra-regional monetary cooperation and exchange rate surveillance. In this paper, we aim to verify whether the East Asian currencies follow a trend of convergence over the long run, by using the adjusted AMU deviation indicators.

The results of our empirical analysis show that the adjusted AMU deviation indicators follow non-stationary processes, as shown by the unit root test. This means that the adjusted AMU deviation indicators of East Asian currencies do not have the property of mean reversion and that the indicators diverge from each other in the long run. Meanwhile, we also examined whether the adjusted indicators follow a similar trend of fluctuation over the long run by using the error correction model. Of 57 combinations of six ASEAN currencies, 18 combinations have relationships of cointegration. Of these 18 combinations, 16 were rejected in an analysis of the statistical significance of the cointegration vector and the adjustment vector, and the other two were rejected by the consistency of the cointegration vector's sign (positive or negative). Thus, it is obvious that the exchange rates of East Asian countries respond to each other asymmetrically. In order to stabilize the macroeconomic variables of East Asian countries, it is important that exchange rate misalignment be addressed.

This paper is organized as follows. In section 1, we provide an outline of the paper as a whole. In section 2, we review previous studies on the measurements of exchange rate surveillance, which include the AMU, the AMU deviation indicator, and the adjusted AMU deviation indicator. In section 3, we clarify the economic implications of conducting a unit root test and cointegration test on the adjusted AMU deviation indicators. In section 4, we employ data from the adjusted AMU deviation indicators to test the stationarity of six ASEAN currencies through a unit root test, identify the long-term relationships between East Asian currencies through a cointegration test, and, finally, discuss the results of our empirical analysis. In section 5, we discuss the contributions of this paper and directions for future research.

## 2. AMU, AMU Deviation Indicator and Adjusted AMU Deviation Indicator for Intra-Regional Exchange Rate Surveillance

After the Asian currency crisis of 1997, the monetary authorities of East Asian countries realized the importance of intra-regional monetary cooperation. Unfortunately, the exchange rate fluctuations in East Asian currencies are still asymmetric and some East Asian countries maintain strong interconnecting relationships with the US dollar. Ogawa (2004) pointed out that the exchange rate fluctuations of East Asian currencies could be divided into two groups from the viewpoint of the asymmetric exchange rate response, and that intra-regional exchange rate misalignment was caused by asymmetric exchange rate fluctuations.[1] In order to detect or prevent exchange rate misalignment in its early stages, it is necessary for the monetary authorities of East Asian countries to monitor intra-regional exchange rates. To establish an intra-regional exchange rate surveillance system, the AMU, AMU deviation indicator, and adjusted AMU deviation indicator have been proposed by Ogawa and Shimizu (2005) and Ogawa and Wang

(2012).

*2.1 Asian Monetary Unit (AMU)*

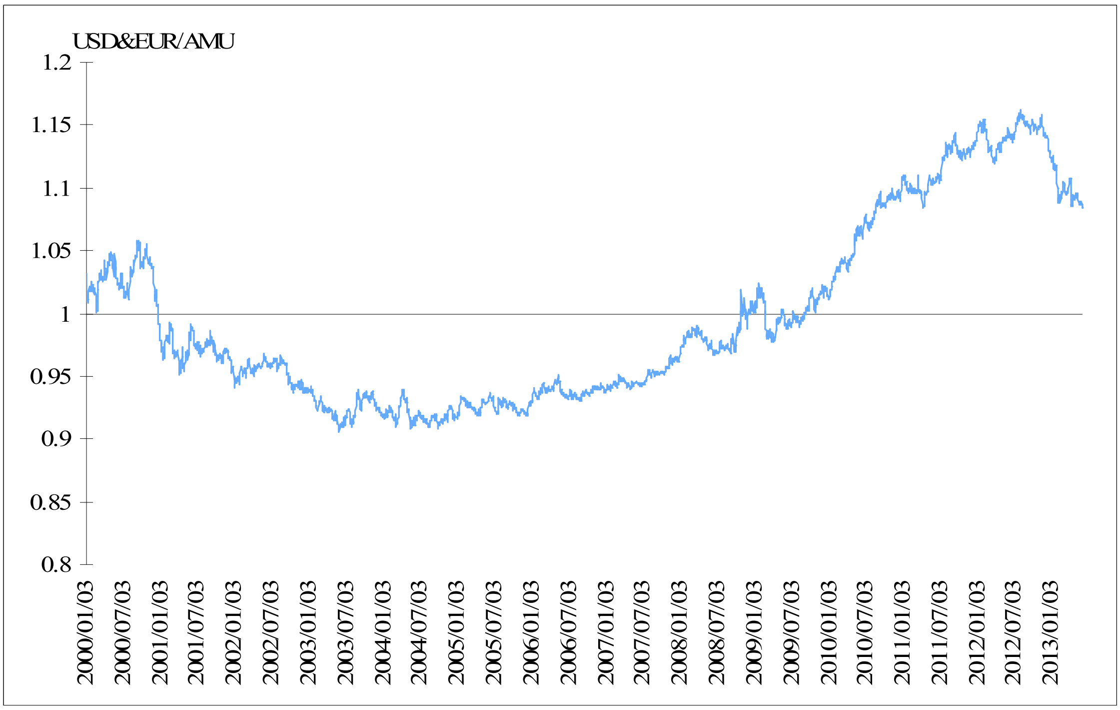
In the aftermath of the Asian Currency Crisis, policymakers and academics recognized that it is necessary for the monetary authorities of East Asian countries to implement a surveillance system that can monitor intra-regional exchange rates, in order to eliminate exchange rate misalignment. The most effective measurement of surveillance is believed to be the employment of a common currency basket (i.e., Williamson, 1999; Williamson, 2001). With this in mind, Ogawa and Shimizu (2005) devised a new currency basket known as the Asian monetary unit (AMU). The AMU is a currency basket unit that is calculated based on the weighted average of the currencies of ASEAN+3 and follows the same procedures used to calculate the European Currency Unit (ECU). Each currency's weight in the currency basket is based on the share of GDP and trade volume. Because both the United States and the euro area are important trading partners of the East Asian countries, the AMU is denominated based on a weighted average of the US dollar and the euro. A weighted average of the US dollar and the euro vis-à-vis the AMU can be expressed as follows:[2]

$$\begin{aligned}\frac{USD\,\&\,EUR}{AMU} = {} & 0.0039\times\frac{USD\,\&\,EUR}{BND} + 6.5556\times\frac{USD\,\&\,EUR}{KHR} + 3.1592\times\frac{USD\,\&\,EUR}{CNY} \\ & + 490.0725\times\frac{USD\,\&\,EUR}{IDR} + 25.3757\times\frac{USD\,\&\,EUR}{JPY} + 121.6898\times\frac{USD\,\&\,EUR}{KRW} \\ & + 10.0825\times\frac{USD\,\&\,EUR}{LAK} + 0.1802\times\frac{USD\,\&\,EUR}{MYR} + 0.0212\times\frac{USD\,\&\,EUR}{MMK} \\ & + 0.9570\times\frac{USD\,\&\,EUR}{PHP} + 0.1120\times\frac{USD\,\&\,EUR}{SGD} + 1.9481\times\frac{USD\,\&\,EUR}{THB} \\ & + 310.3313\times\frac{USD\,\&\,EUR}{VND}\end{aligned} \tag{1}$$

where USD denotes the US dollar, EUR denotes the euro, BND denotes the Brunei dollar, KHR denotes the Cambodian riel, CNY denotes the Chinese yuan, IDR denotes the Indonesian rupiah, JPY denotes the Japanese yen, KRW denotes the Korean won, LAK denotes the Laos kip, MYR denotes the Malaysian ringgit, MMK denotes the Myanmar kyat, PHP denotes the Philippine peso, SGD denotes the Singapore dollar, THB denotes the Thai baht, and VND denotes the Vietnamese dong.

Figure 1 shows the exchange rate of the US dollar and the euro vis-à-vis the AMU from the beginning of 2000 to May of 2013. The AMU was clearly weaker than a weighted average of the US dollar and the euro from late 2000 until the end of 2008. Over that period, many East Asian currencies depreciated against the US dollar and the euro, due to active capital flows such as the yen carry trade. However, the trend of depreciation appeared to stagnate in the middle of 2005, when the Chinese monetary authority made an announcement regarding the reform of its foreign exchange regime. From the end of 2005, the AMU appreciated against the US dollar and the euro, and followed a significant uptrend of appreciation after the bankruptcy of Lehman Brothers. Some of the euro member countries plunged into a serious debt crisis at the time, and the excessive depreciation of the euro particularly accelerated the appreciation of the AMU.

Figure 1. Exchange Rate of Asian Monetary Unit




Source: RIETI online database.

## *2.2 AMU Deviation Indicator*

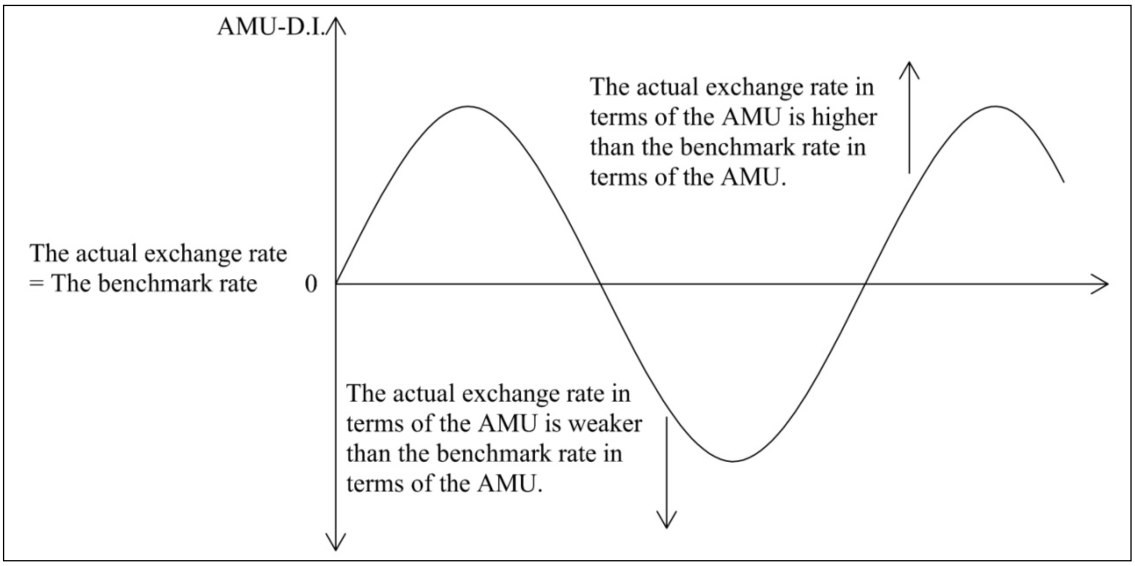
In strengthening surveillance over intra-regional exchange rates, the AMU deviation indicator is considered to be useful for monitoring exchange rate misalignments of the East Asian currencies. The AMU deviation indicator is derived from the exchange rate of AMU and a national currency. It is an index for measuring how much an actual exchange rate diverges from the benchmark rate. The AMU deviation indicator is expected to enhance a monetary authority's ability to monitor exchange rate overvaluation or undervaluation, and especially to identify intra-regional exchange rate misalignment.

According to the frequency of data updates and the purposes of the surveillance involved, the AMU deviation indicator can be divided into the nominal AMU deviation indicator, in terms of nominal exchange rate, and the real AMU deviation indicator, by taking into account the inflation rate differential. The nominal AMU deviation indicator represents the differential between an actual exchange rate and the benchmark rate. Therefore, it can be given by the following equation:

$$The\ Nominal\ AMU\ Deviation\ Indicator(\%) = \frac{\left(\frac{AMU}{N.C.}\right)^{Actual} - \left(\frac{AMU}{N.C.}\right)^{Benchmark}}{\left(\frac{AMU}{N.C.}\right)^{Benchmark}} \times 100 \qquad (2)$$

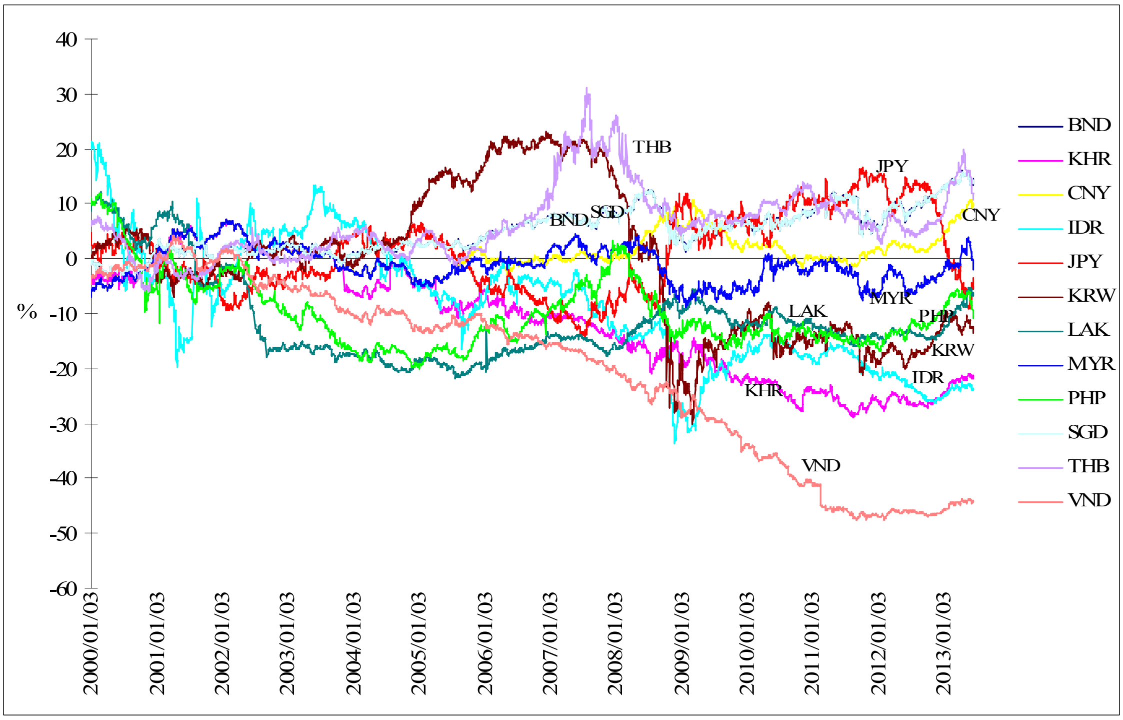
Because the nominal exchange rate, in terms of the AMU vis-à-vis a national currency, can be updated in real time, the nominal AMU deviation indicator is useful for daily real-time exchange rate surveillance. As shown in Figure 2, if the nominal AMU deviation indicator is positive, the exchange rate of the AMU to a national currency is overvalued. If it is negative, the exchange rate of the AMU to a national currency is undervalued. Figure 3 shows the nominal AMU deviation indicator of each currency from the beginning of 2000 to 2013. It clearly shows that fluctuations in the Brunei dollar, the Chinese yuan, the Malaysian ringgit, and the Singapore dollar have been less than 10% in either direction during the whole sample period. Overall, fluctuations in the nominal AMU deviation indicators have increased since around 2005. In particular, after the BNP Paribas shock occurred in the summer of 2007, most East Asian currencies were affected by the substantial depreciation of the euro, and the divergence spread of the nominal AMU deviation indicators between the maximum and the minimum was near to 70%.

Figure 2. Overvaluation or Undervaluation of the AMU Deviation Indicator




Source: RIETI online database.

Figure 3. Nominal AMU Deviation Indicators




Note: The monetary authority of Myanmar officially announced the introduction of floating exchange rate system in April 2012. Nevertheless, the official exchange rates issued by the monetary authority are different from the market rates under the floating exchange rate system. Additionally, Datastream, which is a data source for the AMU, does not yet reflect the market rates for Myanmar. Until Datastream adopts the market rates, Myanmar's AMU deviation indicator will be put on hold. However, as the weight of the Myanmar kyat in the AMU is less than 0.5%, the tentative measurement will not affect the performances of the AMU and the AMU deviation indicators.
Source: RIETI online database.

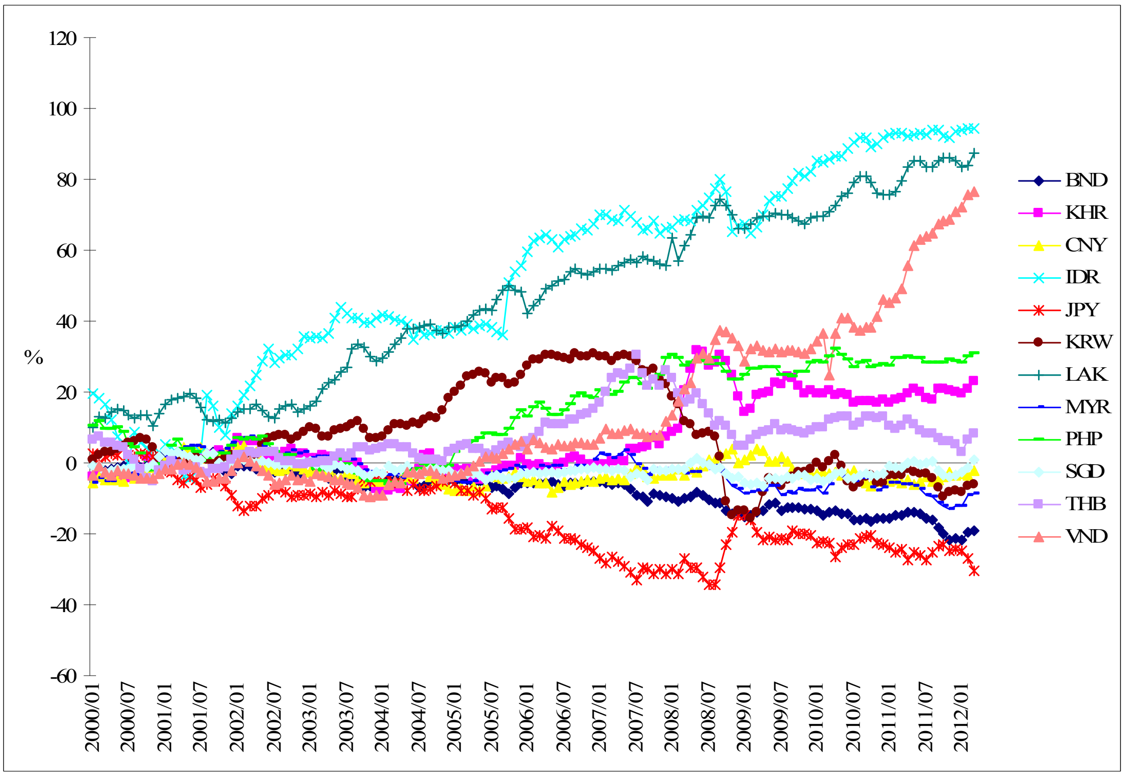
On the other hand, the real AMU deviation indicator can be calculated by taking into account inflation rate differentials, and can be expressed by the following equation:

$$\begin{aligned}&\textit{The Rate of Change of Real AMU Deviation Indicator } (\%)\\&= \textit{The Rate of Change in Nominal AMU Deviation Indicator of Country } "i" - \left(\dot{P}_{AMU} - \dot{P}_i\right)\end{aligned} \tag{3}$$

where $\dot{P}_{AMU}$ is the inflation rate of ASEAN+3 and $\dot{P}_i$ is the inflation rate of country $"i"$.

Due to data constraints, the real AMU deviation indicator can only be calculated monthly, and time lags occur in updating the latest data. The real AMU deviation indicator is thus more useful when the priority is to focus on exchange rate effects on real economic variables such as trade volume and real GDP. Figure 4 shows the real AMU deviation indicators of the East Asian currencies. It makes it clear that these indicators tend to be overvalued in high-inflation countries such as Indonesia, Laos, and Vietnam. However, they tend to be undervalued in deflationary countries such as Japan. The divergence spread among East Asian currencies has broadened since roughly 2005, and especially in recent years. Since the middle of 2012, the divergence spread between the maximum and the minimum of the real AMU deviation indicators has been near to 120%.

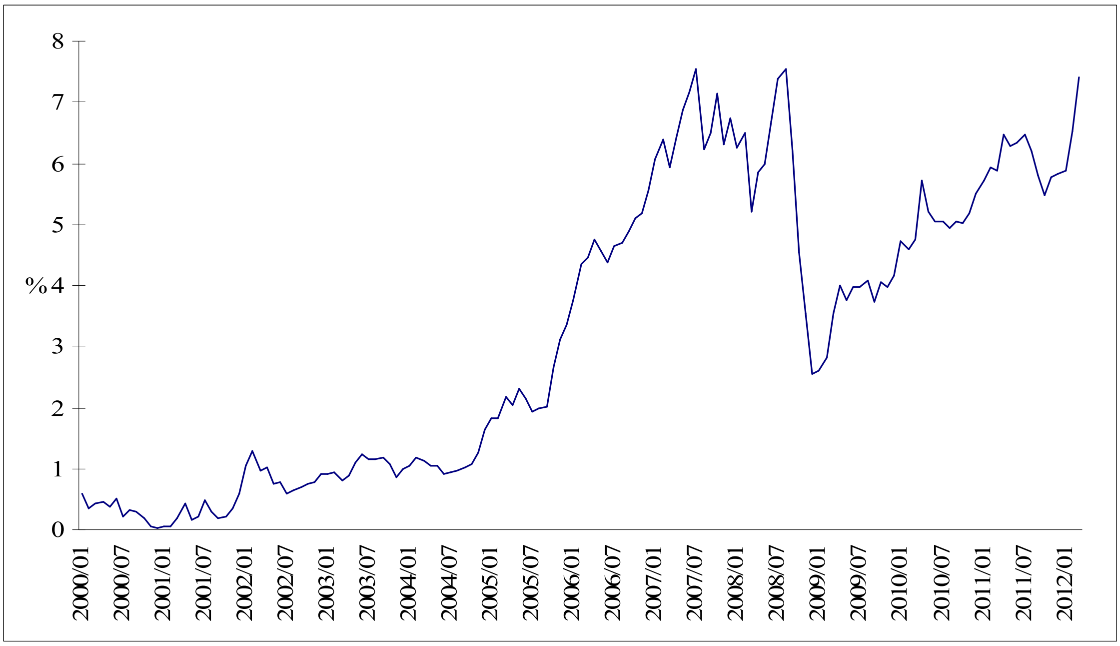
Figure 4. Real AMU Deviation Indicators




Source: RIETI online database.

Based on the weighted average variance of the real AMU deviation indicators, as shown in Figure 5, it is clear that the weighted average variance of these indicators rose rapidly from the end of 2004 to the summer of 2007.[3] The main reason for this is that the Japanese yen was undervalued by approximately 35% and the Korean won was overvalued by approximately 35% during this period. The asymmetric response of these two currencies has the biggest effect on the fluctuation of weighted average variance. However, the divergence spread between the Japanese yen and the Korean won decreased since the middle of 2008, which made the weighted average variance of the real AMU deviation indicators decline drastically. After 2009, the weighted average variance of the real AMU deviation indicators showed an upward trend of fluctuation, because the Japanese yen was undervalued by more than 20%, while the other main East Asian currencies remained at a relatively steady level in the same period.

Figure 5. Weighted Average Variance of Real AMU Deviation Indicators




Source: RIETI online database.
Author's calculation.

*2.3 AMU Deviation Indicator Adjusted by the Balassa–Samuelson Effect*

Ogawa and Wang (2012) employed purchasing power parity (PPP) as a new benchmark rate, and calculated the PPP-based AMU deviation indicator. Due to data constraints, they used consumer price index (CPI) data to calculate the PPP of each East Asian currency. Therefore, the PPP might have been affected by using the data of CPI, which includes the price of non-tradable goods and have tended to diverge from the exchange rate, following the law of one price. In general, the growth rate of productivity in the tradable goods sectors is higher than that in the non-tradable goods sectors. Thus, the rate of inflation in the price of tradable goods tends to be lower than that for non-tradable goods, and the PPP based on the CPI differs from the exchange rate based on the law of one price for tradable goods. The difference between them is known as the Balassa–Samuelson effect.[4] Ogawa and Wang (2012) took the Balassa–Samuelson effect into consideration and adjusted the PPP-based AMU deviation indicator by the

Balassa–Samuelson effect. The adjusted AMU deviation indicator is given by the following equation:

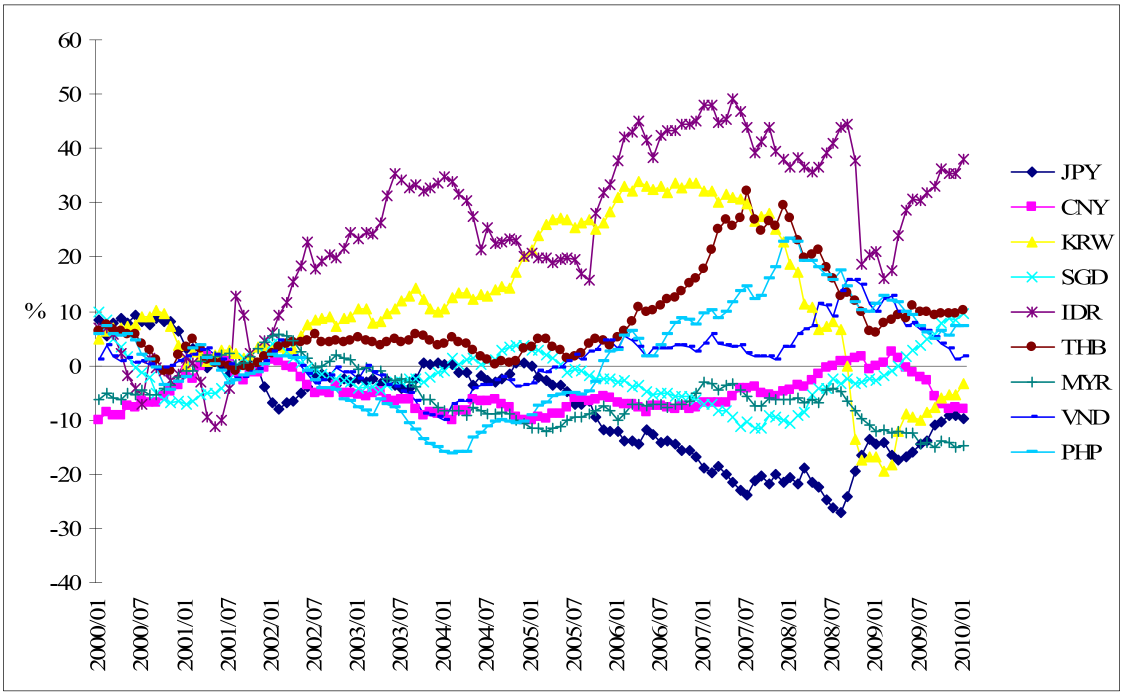
$$\Delta\, DI^{PPP\ Adjusted\ by\ BS} \approx \Delta\, DI^{PPP} + \omega_N \cdot (\dot{\alpha}_T - \dot{\alpha}_N) - \omega_N^* \cdot (\dot{\alpha}_T^* - \dot{\alpha}_N^*) \qquad (4)$$

where $\Delta\, DI^{PPP\ Adjusted\ by\ BS}$ is the rate of change in adjusted AMU deviation indicator, $\Delta\, DI^{PPP}$ is the rate of change in PPP-based AMU deviation indicator, $\omega_N$ is the weight of non-tradable goods with regard to the general price level of the domestic economy, $\dot{\alpha}_T$ is the rate of change in productivity in the tradable goods sectors of the domestic economy, $\dot{\alpha}_N$ is the rate of change in productivity in the non-tradable goods sectors of the domestic economy, $\omega_N^*$ is the weight of non-tradable goods with regard to the general price level of the foreign economy, $\dot{\alpha}_T^*$ is the rate of change in productivity in the tradable goods sectors of the foreign economy, and $\dot{\alpha}_N^*$ is the rate of change in productivity in the non-tradable goods sectors of the foreign economy.

The adjusted AMU deviation indicator also involves a problem with time lags in updating the latest data, as well as the real AMU deviation indicator. The adjusted AMU deviation indicator is thus more useful in evaluating whether an exchange rate is at an appropriate level, by considering equilibrium exchange rates and the growth rate of productivity.[5] Figure 6 shows the adjusted AMU deviation indicators of ASEAN6+3. There is a tendency for the Japanese yen, the Chinese yuan, and the Malaysian ringgit to be undervalued, while there is a tendency for the Korean won, the Indonesian rupiah, the Thai baht, the Vietnamese dong, and the Philippine peso to be overvalued. The Singapore dollar tends to be balanced over the entire sample period. The divergence spread between the maximum and the minimum was near to 80% after the bankruptcy of Lehman Brothers, and was smaller than the disparity in the real AMU deviation indicators.

By comparing the nominal and real AMU deviation indicators with the adjusted AMU deviation indicator, we found that the adjusted AMU deviation indicator shows a similar trend of fluctuation to the real AMU deviation indicator, but involves different movements from the nominal AMU deviation indicator. For example, in Japan, the Japanese yen was undervalued by approximately 35% in terms of the real AMU deviation indicator in 2008, and was similarly undervalued, by approximately 25%, in terms of the adjusted AMU deviation indicator in the same period. However, focusing on the nominal AMU deviation indicator shows that the Japanese yen has tended to be overvalued since 2008. In China, the Chinese yuan tended to be overvalued, in terms of the nominal AMU deviation indicator, after the bankruptcy of Lehman Brothers, while it was undervalued in terms of both the real and adjusted AMU deviation indicators in the same period.

Figure 6. PPP-based AMU Deviation Indicators Adjusted by the Balassa–Samuelson Effect




Source: RIETI Discussion Paper Series 12-E-078.

In order to stabilize the real effective exchange rate and eliminate failures to cooperate on exchange rate policy, it is necessary for the monetary authorities of East Asian countries to engage in policy coordination. The best means of achieving policy coordination on exchange rates is to implement an exchange rate policy based on a common currency basket. As mentioned above, the AMU and other deviation indicators are useful for engaging in intra-regional monetary cooperation and exchange rate coordination. These indicators are particularly expected to make it easier to detect intra-regional exchange rate misalignments in their early stages. However, the meaning of intra-regional monetary cooperation will vary depending on whether exchange rate fluctuations follow similar trends over the long run. If exchange rate fluctuations can be expressed as having a linear relationship, this means that they will converge with each other and that exchange rate misalignments among currencies will diminish over the long term. Therefore, it is inconceivable that the pricing competitiveness of tradable goods or the trade balance will be aggravated by countries with links to the same cointegration relationships. In other words, if there are cointegration relationships among exchange rate fluctuations, the exchange rate fluctuations will have little impact on the macroeconomic variables relating to exchange rate. Conversely, if the exchange rate fluctuations cannot be explained by a linear relationship, it will mean that exchange rate misalignments will continue over the long run. In order to eliminate long-term exchange rate misalignments, it will be necessary to engage in intra-regional monetary cooperation. Therefore, clarifying the stationarity and cointegration relationships of East Asian currencies has important implications.

## 3. Economic Implications of Unit Root Test and Cointegration Test

Generally, fluctuations of macroeconomic variables such as GDP and inflation rate follow time trends, along with economic growth. Until the early 1980s, macroeconomic variables were usually assumed to follow certain trends. After that, with the clarification of non-stationary stochastic process and the introduction of the new concepts of "unit root" and "cointegration," a new approach to time series analysis was established. In this section, we first briefly explain the concepts of "unit root" and "cointegration," and then clarify what their economic implications are by employing two concepts.

### *3.1 Unit Root and Cointegration*

In time series analyses, data are often supposed to follow a stationary process. When a stochastic process satisfies the property of stationarity, it implies that its mean is zero, variance converges to a specific value, and covariance depends on an intertemporal differential. On the other hand, if a stochastic process does not have the property of stationarity, it indicates that its mean, variance, and covariance diverge.[6] Furthermore, with respect to the non-stationary process called random walk, the process's mean is equal to its initial value, and both variance and covariance diverge. When original data series involve random walk and their first-order differences are stationary, random walk is referred to as a unit root process. In a regression model with unit root processes, if error terms follow a non-stationary stochastic process, the regression model is said to involve spurious regression. However, if the error terms follow a stationary stochastic process, the original data series are thought to have a relationship of cointegration. Non-stationary stochastic processes are cointegrated over the long run, which also means that they interact with each other, and that there are long-term equilibrium relationships among the original data series.

### *3.2 Economic Implications of Unit Root Test and Cointegration Test on the Adjusted AMU Deviation Indicators*

By testing whether the adjusted AMU deviation indicators follow unit root processes, we can clarify the properties of the adjusted AMU deviation indicators.[7] If the null hypothesis that the adjusted AMU deviation indicators follow unit root processes is rejected, it means that any divergence that is currently occurring is temporary, and will vanish over the long run. On the other hand, if the null hypothesis cannot be rejected, it means that the adjusted AMU deviation indicators are affected by factors that will make divergence continue over the long run. One factor can be a structural problem with the foreign exchange regime. As the AMU is a currency basket, the exchange rate of each currency, in terms of the AMU, also reflects a relationship of the home currency with the weighted average of the whole area. Unless each country adopts the same or a similar foreign exchange regime, the exchange rate fluctuations of East Asian currencies will differ from each other.

On the other hand, if the adjusted AMU deviation indicators follow unit root processes, it is necessary to examine whether there cointegration relationships exist among the non-stationary processes. The reason for this is that fluctuations in the adjusted AMU deviation indicators may be related to each other over the long term. If the adjusted AMU deviation indicators are confirmed to converge over the long run, it means that the exchange rate fluctuations of these currencies can be explained by a linear relationship. In other words, exchange rate misalignments happening over the short term will converge with each other over the long term.

Although a linear relationship implies that there are cointegration relationships among the adjusted AMU deviation indicators, the meaning of cointegration differs based on the significance of the cointegration vector and the adjustment vector. In other words, a cointegration relationship cannot be accepted unless the test statistics of the cointegration vector and the adjustment vector are statistically significant. Furthermore, the signs of the cointegration and adjustment vectors are also important factors in the interpretation of the meaning of cointegration. If the test statistics of the cointegration and adjustment vectors are statistically significant, the exchange rate fluctuations will not converge unless the signs of the vectors are consistent. In other words, short-term exchange rate misalignments converge over the long run only if the test statistics of the two vectors are statistically significant and the sign of the vectors fulfills the requirement of consistency. Therefore, we can identify whether the exchange rate fluctuations of East Asian currencies will converge over the long run by performing a cointegration test. Monetary cooperation should occur among countries whose currencies were involved in exchange rate misalignments.

## 4. Empirical Analysis

### *4.1 Data and Sample Period*

As mentioned above, we employ the adjusted AMU deviation indicator to analyze to the stationarity of East Asian currencies.[8] The calculation of the adjusted AMU deviation indicator is as follows. First, the PPP-based AMU deviation indicator is calculated by using the AMU and the price level of each country.[9] Secondly, the Balassa–Samuelson effect of each currency is calculated. Finally, the adjusted AMU deviation indicator is calculated by referring to the PPP-based AMU deviation indicator and the Balassa–Samuelson effect.[10]

The sample period is from January 2000 to August 2008, just before the bankruptcy of Lehman Brothers.[11]

### *4.2 Methodology*

We identify whether divergence between the actual exchange rates and the benchmark exchange rates will continue over the long run based on a unit root test, using the adjusted AMU deviation indicator. The unit root test and test statistics are based on Dickey and Fuller (1979), under the assumption that the adjusted AMU deviation indicator follows the $AR(p)$ process, and the $AR(p)$ process is as follows:

$$DI_t = \rho_1 DI_{t-1} + \rho_2 DI_{t-2} + \rho_3 DI_{t-3} + \cdots + \rho_p DI_{t-p} + u_t,\ u_t \sim iid\left(0, \sigma^2\right) \qquad (5)$$

The null and alternative hypotheses based on the augmented Dickey–Fuller test are as follows:[12]

$$H_0 \ :\ |\psi| = 1 \quad vs. \quad H_1 \ :\ |\psi| < 1 \qquad (6)$$

where $\psi = \rho_1 + \rho_2 + \rho_3 + \cdots + \rho_p$.

The null hypothesis indicates that the stochastic process follows a unit root process and that the data series are non-stationary, while the alternative hypothesis indicates that the stochastic process does not follow a unit root process and that the data series are stationary.[13] According to the unit root test, if the adjusted AMU deviation indicator follows a unit root process, this implies that divergence will continue over the long run.

When the adjusted AMU deviation indicators follow unit root processes, it is necessary to identify whether cointegration relationships exist over the long run. In this case, a cointegration test can be employed to determine cointegration relationships. The error correction model that is used in the cointegration test is as follows:

$$\Delta DI_t = \sum_{k=1}^{p-1} \Gamma_k \Delta DI_{t-k} + \Pi DI_{t-1} + \varepsilon_t \qquad (7)$$

where $\Pi = \alpha\beta'$, $\alpha$ is a matrix in terms of adjustment vectors, $\beta'$ is a matrix in terms of cointegration vectors, $DI_{t-1}$ is a $n \times 1$ vector, and $DI_{t-1} = \left(DI_{1,t-1}, DI_{2,t-1}, \cdots, DI_{n,t-1}\right)'$.

On the other hand, the number of cointegration relationships will change according to lag order. It is therefore important to choose an appropriate lag order, in order to identify the number of cointegration relationships. We assume that each stochastic process is affected by the previous shocks and that the shocks last one year. Under these assumptions, the selection of lag order will begin with two, and the order will increase gradually, with the best order selected from 12 final possibilities. We base our criteria for choosing a lag order on Ljung–Box test statistics and Lagrange multiplier test statistics. We select a lag order without serial correlation but with cointegration relationships. If there are two or more lag orders that fulfill the criteria of selection, we also consider other benchmarks, based on the information criteria. With respect to the information criteria, the Akaike information criteria (AIC) and the Schwartz Bayes information criteria (SBIC) can be effectively used, but it is not always appropriate to choose the same model based on the two information criteria. We thus employ SBIC on the basis of the work of Juselius (2006). We also employ Hannan and Quinn (HQ) statistics because of our sample size.[14]

Furthermore, in order to determine the characteristics of each data series in the cointegration system, we conduct three additional Chi-square tests on the cointegration vector and the adjustment vector. The null hypotheses of the three additional Chi-square tests are as follows:

(a) Any data series do not include in the long-term equilibrium relationships. In other words, although the data series are included in the cointegration system, the test statistics are not statistically significant over the long run.

(b) Any data series that are included in the cointegration system satisfy the property of stationarity, but the property of stationarity does not relate to other cointegration vectors.

(c) Any data series that are included in the cointegration system have the property of weak exogeneity over the long run.

The additional tests (a) and (c) are useful for identifying a cointegration relationship. Because the number of cointegration relationships varies depending on lag order, there is a possibility of over-identification or under-identification in selecting a model. However, the risk of erroneous identification in model selection can be reduced by testing the relationships of data series over the long run, as well as data series exogeneity. On the other hand, the additional test (b) can identify whether error correction mechanisms are based on exogenous factors such as individual effects on error terms. In order to clarify the characteristics of exchange rate misalignments among East Asian currencies, it is necessary to focus on the combinations in which the adjusted AMU deviation indicators have strong correlationships. We aim to identify the relationships between exchange rate fluctuations, and thus, expect the cointegration system to develop the stationarity of data series. Therefore, it is important to use three additional tests to identify these relationships.

*4.3 Empirical Analysis Results*

Tables 1 and 2 show the results of a unit root test of each country's adjusted AMU deviation indicator. The null hypothesis stating that the adjusted AMU deviation indicator follows a unit root process cannot be rejected. It is thus clear that the adjusted AMU deviation indicator of each country is non-stationary. Therefore, the candidates for a test of cointegration relationships combine two currencies at least and six currencies at most, and the total number of combinations is 57.

Since the error term of the error correction model does not allow for serial correlations, we checked the properties of each combination's error term. Out of 57 combinations, 18 were considered not to involve serial correlation. We thus focused on the 18 combinations and conducted three additional tests under the alternative hypotheses that each data series is included in the long equilibrium relationships, that the stationarity of each data series is significantly relevant to cointegration vectors, and that each data series does not have the property of weak exogeneity.[15] The test results are summarized in Table 3. For example, with respect to Singapore, there are 13 combinations that are cointegrated over the long run. Of these, 13 out of 13 are significantly included in a long-term relationship, while in 11 out of 13, stationarity is significantly relevant to cointegration vectors, and in 12 out of 13, the data series do not have the property of weak exogeneity.

With respect to the whole East Asian area, most of the combinations without serial correlations involve the Singapore dollar. Out of 18 combinations, 13 were found to have this tendency, the reason for which could be the currency basket regime adopted by the monetary authority of Singapore. On the other hand, in focusing on the currencies of the whole area, combinations based on the Singapore dollar and the Indonesian rupiah as well as the Singapore dollar and the Thai baht show that the Singapore dollar, the Indonesian rupiah, and the Thai baht have the tendency to cointegrate. This is because Indonesia is the second-largest economy in the region, Thailand maintains its economic growth rate at roughly 6%, and both of these countries are important trading partners of Singapore. As such, the monetary authority of

Singapore is conscious of the two currencies and takes both them into consideration in its decisions on basket currencies.

Table 1. Unit Root Test (with intercept)

| Unit Root Test (ADF) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Currency | Test Statistics | | Currency | Test Statistics | | Currency | Test Statistics | |
| | Level | 1st Diff. | | Level | 1st Diff. | | Level | 1st Diff. |
| SGD | -2.81* | -6.97*** | THB | -1.20 | -7.64*** | VND | -0.10 | -9.31*** |
| IDR | -0.97 | -8.36*** | MYR | -1.40 | -7.99*** | PHP | -0.71 | -6.60*** |
| **Unit Root Test (PP)** | | | | | | | | |
| Currency | Test Statistics | | Currency | Test Statistics | | Currency | Test Statistics | |
| | Level | 1st Diff. | | Level | 1st Diff. | | Level | 1st Diff. |
| SGD | -3.18** | -7.08*** | THB | -1.10 | -7.67*** | VND | -0.44 | -9.49*** |
| IDR | -0.98 | -8.22*** | MYR | -1.39 | -8.01*** | PHP | -0.30 | -6.56*** |
| **Unit Root Test (KPSS)** | | | | | | | | |
| Currency | Test Statistics | | Currency | Test Statistics | | Currency | Test Statistics | |
| | Level | 1st Diff. | | Level | 1st Diff. | | Level | 1st Diff. |
| SGD | 0.47** | 0.16 | THB | 0.70** | 0.15 | VND | 0.48** | 0.28 |
| IDR | 1.00*** | 0.07 | MYR | 0.51** | 0.16 | PHP | 0.52** | 0.53** |

Note: SGD denotes the Singapore dollar, IDR denotes the Indonesian rupiah, THB denotes the Thai baht, MYR denotes the Malaysian ringgit, VND denotes the Vietnamese dong, and PHP denotes the Philippine peso.

*** denotes significance at the 1% level.

** denotes significance at the 5% level.

* denotes significance at the 10% level.

Source: RIETI Discussion Paper Series 12-E-078.

Author's calculation.

Table 2. Unit Root Test (with linear trend and intercept)

| Unit Root Test (ADF) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Currency | Test Statistics | | Currency | Test Statistics | | Currency | Test Statistics | |
| | Level | $1^{st}$ Diff. | | Level | $1^{st}$ Diff. | | Level | $1^{st}$ Diff. |
| SGD | -2.61 | -7.05*** | THB | -2.13 | -7.61*** | VND | -0.87 | -9.66*** |
| IDR | -2.73 | -8.32*** | MYR | -1.69 | -7.95*** | PHP | -1.83 | -6.93*** |
| **Unit Root Test (PP)** | | | | | | | | |
| Currency | Test Statistics | | Currency | Test Statistics | | Currency | Test Statistics | |
| | Level | $1^{st}$ Diff. | | Level | $1^{st}$ Diff. | | Level | $1^{st}$ Diff. |
| SGD | -3.03 | -7.19*** | THB | -1.91 | -7.64*** | VND | -1.06 | -9.73*** |
| IDR | -2.46 | -8.17*** | MYR | -1.75 | -7.97*** | PHP | -1.44 | -6.54*** |
| **Unit Root Test (KPSS)** | | | | | | | | |
| Currency | Test Statistics | | Currency | Test Statistics | | Currency | Test Statistics | |
| | Level | $1^{st}$ Diff. | | Level | $1^{st}$ Diff. | | Level | $1^{st}$ Diff. |
| SGD | 0.12* | 0.10 | THB | 0.21** | 0.13* | VND | 0.24*** | 0.06 |
| IDR | 0.10 | 0.07 | MYR | 0.15** | 0.16** | PHP | 0.30*** | 0.06 |

Note: SGD denotes the Singapore dollar, IDR denotes the Indonesian rupiah, THB denotes the Thai baht, MYR denotes the Malaysian ringgit, VND denotes the Vietnamese dong, and PHP denotes the Philippine peso.
*** denotes significance at the 1% level.
** denotes significance at the 5% level.
* denotes significance at the 10% level.
Source: RIETI Discussion Paper Series 12-E-078.
Author's calculation.

Table 3. Additional Test Results

| | Additional Test (a) | Additional Test (b) | Additional Test (c) |
|---|---|---|---|
| Singapore | 13(13) | 11(13) | 12(13) |
| Indonesia | 6(12) | 12(12) | 5(12) |
| Thailand | 6(7) | 7(7) | 3(7) |
| Malaysia | 3(7) | 7(7) | 3(7) |
| Vietnam | 9(12) | 11(12) | 5(12) |
| The Philippines | 5(7) | 6(7) | 3(7) |

Note: The last three columns represent how many null hypotheses are rejected in additional tests (a), (b), and (c). The number of cointegration relationships is shown in parentheses.
Source: RIETI Discussion Paper Series 12-E-078.
Author's calculation.

Furthermore, the combinations for which the three additional tests are simultaneously significant are the Indonesian rupiah and the Vietnamese dong, and the Singapore dollar, the Indonesian rupiah and the Philippine peso. The error correction models of the two combinations can be expressed as follows.

With respect to the Indonesian rupiah and the Vietnamese dong, the error correction model can be expressed by the following linear combination:

$$\begin{pmatrix} \Delta IDR \\ \Delta VND \end{pmatrix} = \sum_{k=1}^{2-1} \Gamma_k \begin{pmatrix} \Delta IDR \\ \Delta VND \end{pmatrix}_{t-k} + \begin{pmatrix} -0.75 \\ -0.47 \end{pmatrix} \begin{pmatrix} 0.13 & 0.13 \end{pmatrix} \begin{pmatrix} IDR \\ VND \end{pmatrix}_{t-1} + \begin{pmatrix} \varepsilon_{IDR} \\ \varepsilon_{VND} \end{pmatrix}_t \qquad (8)$$

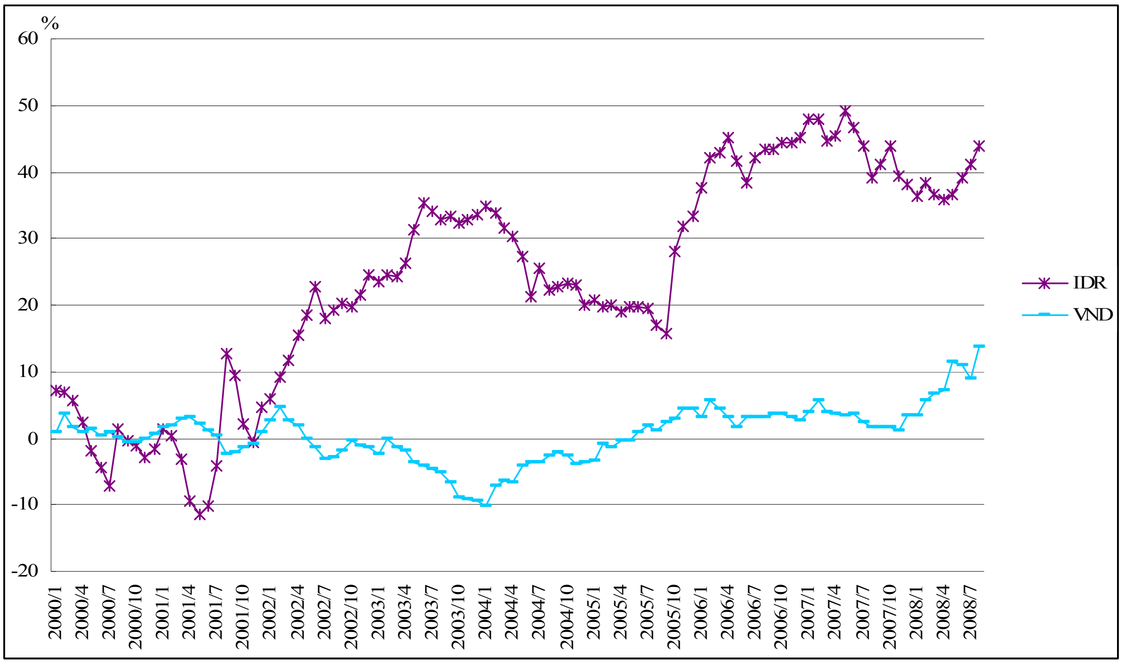
where IDR denotes the Indonesian rupiah and VND denotes the Vietnamese dong.

The linear combination of the two currencies over the long run can be expressed as follows:

$$IDR = -1.01 VND + u_{IDR} \qquad (9)$$

As the sign of combination of the Indonesian rupiah and the Vietnamese dong is negative, the adjusted AMU deviation indicators of the two currencies follow an adverse long-term trend of fluctuation, which means that the exchange rate misalignments of the two currencies do not converge over the long run. This can be explained by the fluctuations of the nominal AMU deviation indicator, as well as the inflation rate. The nominal AMU deviation indicator of the Indonesian rupiah tended to be slightly undervalued or balanced during the whole sample period, while at the same time, Indonesia was experiencing a high inflation rate. Therefore, the adjusted AMU deviation indicator that is calculated with the PPP-based AMU deviation indicator and the Balassa–Samuelson effect has a tendency toward overvaluation. On the other hand, the nominal AMU deviation indicator of the Vietnamese dong tended to be undervalued during the whole sample period, while the inflation rate in Vietnam was consistently high. The adjusted AMU deviation indicator of the Vietnamese dong thus tended to be balanced or slightly undervalued. For these reasons, the two currencies are following an adverse trend of fluctuation. Figure 7 makes it clear that the Indonesian rupiah and the Vietnamese dong fluctuated in opposite directions.

Figure 7. Adjusted AMU Deviation Indicators (Indonesian rupiah and Vietnamese dong)




Note: IDR denotes the Indonesian rupiah and VND denotes the Vietnamese dong.
Source: RIETI Discussion Paper Series 12-E-078.

With respect to the Singapore dollar, the Indonesian rupiah and the Philippine peso the error correction model can be expressed by the following linear combination:

$$\begin{pmatrix} \Delta SGD \\ \Delta IDR \\ \Delta PHP \end{pmatrix} = \sum_{k=1}^{8-1} \Gamma_k \begin{pmatrix} \Delta SGD \\ \Delta IDR \\ \Delta PHP \end{pmatrix}_{t-k} + \begin{pmatrix} 0.49 \\ 0.62 \\ 0.39 \end{pmatrix} \begin{pmatrix} -0.56 & -0.15 & -0.18 \end{pmatrix} \begin{pmatrix} SGD \\ IDR \\ PHP \end{pmatrix}_{t-1} + \begin{pmatrix} \varepsilon_{SGD} \\ \varepsilon_{IDR} \\ \varepsilon_{PHP} \end{pmatrix}_t \qquad (10)$$

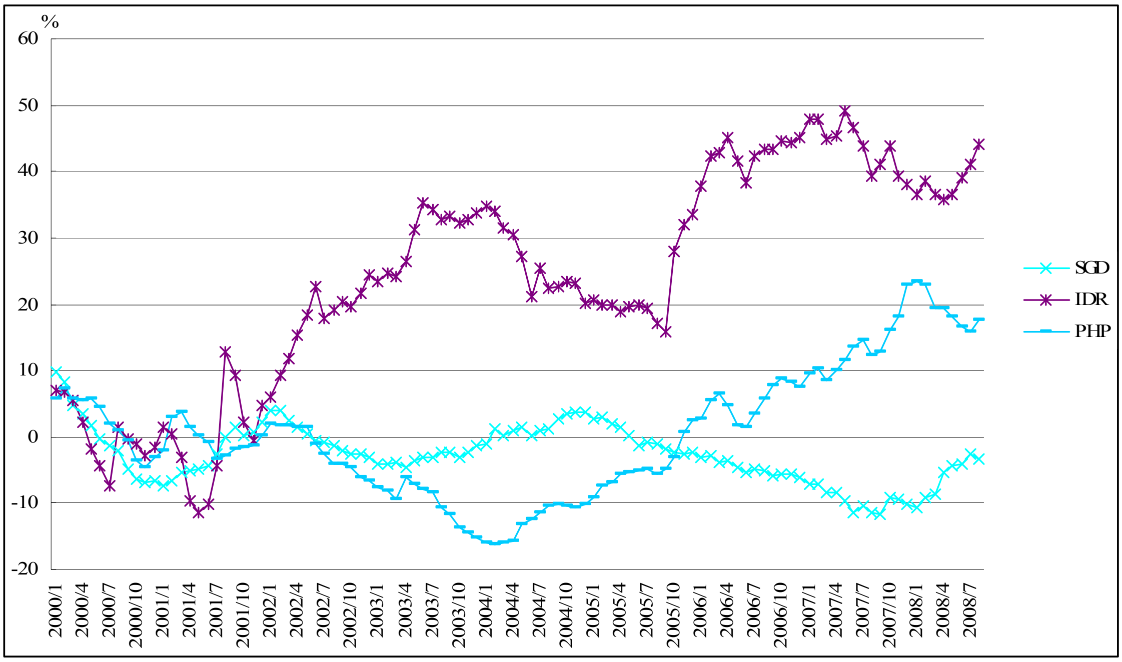
where SGD denotes the Singapore dollar, IDR denotes the Indonesian rupiah and PHP denotes the Philippine peso.

The linear combination of the three currencies over the long run can thus be expressed as follows:

$$SGD = -0.27IDR - 0.32PHP + u_{SGD} \qquad (11)$$

As the sign of combination of the Singapore dollar, the Indonesian rupiah and the Philippine peso is negative, the adjusted AMU deviation indicators of the three currencies follow an adverse long-term trend of fluctuation, which means that the exchange rate misalignments of the three currencies do not converge over the long run. The negative correlationship among the Singapore dollar, the Indonesian rupiah and the Philippine peso is relevant to the foreign exchange regime adopted by the monetary authority of Singapore and a high inflation rate occurred in Indonesia and the Philippines. As Singapore's monetary authority pays attention to the exchange rate of its main trading partners, and tries to stabilize the Singapore dollar with them, which is why the exchange rates of the Singapore dollar fluctuate at stable level. On the other hand, the other two countries, Indonesia and the Philippines, were suffering from a high inflation rate. It is obvious that the adjusted AMU deviation indicators of the Indonesian rupiah and the Philippine peso had a tendency of overvaluation. From Figure 8, it is clear that the Singapore dollar, the Indonesian rupiah and the Philippine peso do not converge.

Figure 8. Adjusted AMU Deviation Indicators (Singapore dollar, Indonesian rupiah and Philippine peso)




Note: SGD denotes the Singapore dollar, IDR denotes the Indonesian rupiah and PHP denotes the Philippine peso.
Source: RIETI Discussion Paper Series 12-E-078.

Hence, we cannot find any combinations for which there is no serial correlation in error terms and the three additional Chi-square tests are significant simultaneously.[16]

## 5. Conclusion

In this paper, we reviewed advanced studies of measurements that could be used to engage in monetary cooperation in the East Asian area. We then investigated the stationarity of East Asian currencies by using the adjusted AMU deviation indicators.

Since the nominal AMU deviation indicators can be calculated on a daily basis, they are useful for real-time surveillance. In contrast, the real AMU deviation indicators and adjusted AMU deviation indicators can be calculated only on a monthly basis and involve time lags in data release. For these reasons, they cannot be applied to monitor exchange rate fluctuations. However, in cases where the priority is to focus on exchange rate effects on real economic variables, such as GDP and trade balance, the real AMU deviation indicators and adjusted AMU deviation indicators are more useful.

On the other hand, based on the results of a unit root test, we found that the adjusted AMU deviation indicators do not have the property of mean reversion. In other words, divergence from the benchmark rate is not a temporary episode but continues over the long run. In order to identify whether long-term cointegration relationships exist, we also employed the error correction model to run a cointegration test. By focusing on combinations composed of at least two and at most six currencies, we found that 18 out of 57 combinations had cointegration relationships. Most of these cointegration relationships were rejected based on their lack of statistical significance, as was shown by the results of three additional tests. The exceptions were the combinations of the Indonesian rupiah and the Vietnamese dong and of the Singapore dollar, the Indonesian rupiah and the Philippine peso. As the sign of the linear combination of the two combinations were negative, both of them could not be accepted for long-run cointegration. Therefore, we cannot find any currencies of which their linear combination is statistically significant. The results of this empirical analysis correspond to the foreign exchange regimes adopted by East Asian countries. Since most East Asian countries follow their own foreign exchange policies, exchange rate fluctuations lack synchronization and exchange rate misalignments do not converge over the long run.

According to the results of our cointegration test, it is clear that the exchange rate fluctuations of East Asian countries are asymmetric. As intra-regional trade is expanding, it is important to detect the asymmetric responses of exchange rates in the early stages in order to stabilize trade balance. We expect that the AMU deviation indicators and the adjusted AMU deviation indicators will be used to monitor intra-regional exchange rates and macroeconomic variables related to exchange rates, and that they can contribute to construct a monetary cooperation system in the East

Asian area. In a future study, we intend to conduct a non-linear approach on cointegration relationship and extend sample period along with data accumulation.

Furthermore, the trilemma of international finance indicates that we have to abandon the liberalization of capital flow or the independence of monetary policy if we hope to stabilize exchange rates. Given the current circumstances of East Asia, it would be difficult to restrict the convertibility of capital accounts through capital control or foreign exchange intervention, and abandoning independent monetary policy would also be unrealistic. One means of solving the problems of the trilemma is to employ a mixed policy based on the combination of monetary and foreign exchange policies under a liberalized capital flow (Ito & Hayashi, 2006). By focusing on mixed policy, monetary authorities could carry out their own monetary policies by setting inflation targets, while, at the same time, adjusting exchange rates by referring to a currency basket. An inflation target could stabilize international capital flow, and foreign exchange policy could indirectly affect inflation rates as a result of pass-through effects. Monetary policy and foreign exchange policy have a complementary relationship in mixed policy. Therefore, policy coordination based on a combination of monetary policy and foreign exchange policy would be suitable to the conditions in the East Asian area.

It has been more than 10 years since the idea of a common currency basket has been considered in East Asia; some nations are not interested in it, and the debate on its introduction and use continues. However, the ability to respond to financial crises is a critical one, and given how a common currency basket can enhance this capacity, now is the time to spark greater interest in the currency basket within the area of East Asia. Doing so is a matter of emphasizing not only one's own national interests, but also those of the entire East Asian region.

## NOTES

1. In Ogawa (2004), the East Asian currencies include the Singapore dollar, the Indonesian rupiah, the Thai baht, the Malaysian ringgit, the Philippine peso, the Chinese yuan, the Korean won, the Hong Kong dollar, and the Taiwanese dollar.

2. The share and weight of each country is based on the 8th version of the AMU. See the AMU website for more detail, at http://www.rieti.go.jp/users/amu/en/index.html.

3. The weighted average variance of the real AMU deviation indicators is calculated based on the weight of each currency in the AMU, as well as the real AMU deviation indicators.

4. As Kohler (2000) mentioned, differences in productivity growth (tradable and nontradable goods sectors) could affect an overall inflation. In the cases of Japan and Germany, both of the two countries showed a trend of tradable goods sectors growth in the 1960s and 1970s. It also shows that there is a dominance of nontradable sectors growth in some developed and developing countries in recent growth trends. With respect to the East Asian area, most of the countries have experienced a growth that is led by productivity growth in the tradable goods sectors (Ogawa & Wang, 2012; Ogawa & Wang, 2013a). The growth patterns of East Asian countries are similar to the growth of Japan and Germany. I am indebted to the anonymous referee for comments on the Balassa–Samuelson effect between European Monetary Union and East Asian area.

5. Since the economic growth model of each country in East Asian area is different, the classification of tradable and non-tradable goods sectors could cause a bias in the growth rates of productivity. Specifically, the growth rates of productivity in the tradable goods sector are affected by technical progress and capital–labor intensity. However, in order to evaluate the exchange rate level and identify the exchange rate misalignments among the East Asian currencies appropriately, it is necessary to keep the benchmark rate at an appropriate level. In a future study, what is needed is to estimate the growth rates of productivity using some new model (for example, by using the Cobb–Douglas production function for calculation), and also introduce some other conceptions of equilibrium exchange rate into studies on the adjusted AMU deviation indicator.

6. Here "the stochastic process's mean, variance, and covariance diverge" implies that the stochastic process's mean does not have the property of mean reversion, and that both variance and covariance are dispersing over time. For example, in an $AR(1)$ process as $y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \varepsilon_{i,t}$, $\varepsilon_{i,t} \sim W.N.(0, \sigma^2)$, the stochastic process's mean, variance, and covariance can be expressed by $E(y_{i,t}) = \beta_i^t y_0$, $\mathrm{var}(y_{i,t}) = \sigma^2 \sum_{l=0}^{t-1} \beta_i^{2l}$, and $\mathrm{cov}(y_{i,t}, y_{i,t-s}) = \beta_i^s \sigma^2 \sum_{l=0}^{t-s-1} \beta_i^{2l}$, respectively. If the stochastic process does not satisfy the property of stationarity, which is $|\beta_i| > 1 \,\&\, t \to \infty$, then the stochastic process's mean, variance, and covariance depend on time $t$.

7. In order to examine the long-term relationships in the East Asian currencies, we focus on the exchange rate misalignments occurring among the currencies, and employ the adjusted AMU deviation indicators to identify the relationships. The reason for this is as follows. The adjusted AMU deviation indicator, in which the benchmark rate is time-varying, can especially dynamically reflect real economic fundamentals. It also takes into account the Balassa–Samuelson effect, and thus exchange rate misalignments

occurring in the East Asian countries can be caught more accurately. Through preventing or narrowing exchange rate misalignments among the East Asian countries, macroeconomic variables such as trade balance and capital flow can be stabilized. Therefore, we use the adjusted AMU deviation indicator as a reference identifying the long-term exchange rate relationships in the East Asian currencies.

8. East Asian currencies consist of the Singapore dollar, the Indonesian rupiah, the Thai baht, the Malaysian ringgit, the Philippine peso and the Vietnamese dong. As mentioned in Ogawa and Kawasaki (2003), some of East Asian currencies are satisfied with the condition of creating a common currency basket, we therefore focus on the most likely candidates, which their currencies are expected to be included in the common currency basket.

9. Due to data constraints, the CPIs are employed as price levels.

10. For more detail, see Ogawa and Wang (2012).

11. The sample period continues until just before the bankruptcy of Lehman Brothers because notable changes in exchange rate fluctuation occurred before and after the bankruptcy. More specifically, although the benchmark exchange rate of the adjusted AMU deviation indicator is given by referring to the fundamental of real economy, and is thought of as robustness, we also need to pay attention to actual exchange rates when we focus on the movement of the adjusted AMU deviation indicator, because the adjusted AMU deviation indicator is calculated with the actual exchange rate as well as the benchmark exchange rate. It is interesting to note how the adjusted AMU deviation indicator fluctuated after the bankruptcy of Lehman Brothers. In our future research, we plan to carry out an additional analysis of the sample period after the bankruptcy of Lehman Brothers, along with the accumulated data.

12. For more detail, see Hamilton (1994).

13. As an additional means of evaluation, we also employ the Phillips–Perron (PP) test. The test statistics are based on Phillips and Perron (1988). The PP test relaxes the limitations of the assumptions of the ADF test, and takes into account the auto-regression of error terms, as well as the heterogeneity of variance. The null hypothesis of the PP test is that the stochastic process follows a unit root process, while the alternative hypothesis is that the stochastic process does not follow a unit root process. On the other hand, it is known that the ADF has low power against stable auto-regressive alternatives with roots near unity. Here we also employ the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test. The test statistics are based on Kwiatkowski, Phillips, Schmidt and Shin (1992). The KPSS test also relaxes the limitations of the assumptions of the ADF test, and takes into account the auto-correlation of error terms. The null hypothesis of the KPSS test is that the stochastic process is stationary, while the alternative hypothesis is that the stochastic process follows a unit root process.

14. For more detail, see Shittu and Asemota (2009) for a comparison between the test statistics of SBIC and HQ.

15. See Appendix for test results.

16. We also check the stationarity of each combination from the aspect of panel unit root test, but we cannot find any combinations are statistically significant. The results of panel unit root test are not reported because of space limitations but are available upon request.

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## Appendix 1(1). Chi-Square Tests

| Combination | | SGD | IDR | THB | MYR | VND | PHP | Combination | | SGD | IDR | THB | MYR | VND | PHP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SGD IDR | P=10 | 5.66$^{**}$ | 0.24 | | | | | SGD IDR VND | P=6 | 13.57$^{***}$ | 3.46$^{*}$ | | | 10.94$^{***}$ | |
| | R=1$^{*}$ | 0.24 | 5.66$^{**}$ | | | | | | R=1$^{**}$ | 11.84$^{***}$ | 16.92$^{***}$ | | | 18.94$^{***}$ | |
| | | 5.25$^{**}$ | 0.24 | | | | | | | 14.24$^{***}$ | 1.49 | | | 0.82 | |
| SGD THB | P=6 | 12.70$^{***}$ | | 5.57$^{**}$ | | | | SGD IDR PHP | P=8 | 27.89$^{***}$ | 17.20$^{***}$ | | | | 26.37$^{***}$ |
| | R=1$^{***}$ | 5.57$^{**}$ | | 12.70$^{***}$ | | | | | R=1$^{***}$ | 27.02$^{***}$ | 30.55$^{***}$ | | | | 37.15$^{***}$ |
| | | 12.39$^{***}$ | | 2.25 | | | | | | 24.90$^{***}$ | 3.45$^{*}$ | | | | 6.70$^{***}$ |
| SGD VND | P=7 | 19.25$^{***}$ | | | | 5.06$^{**}$ | | SGD MYR VND | P=6 | 6.26$^{***}$ | | | 3.40$^{*}$ | 1.16 | |
| | R=1$^{**}$ | 5.06$^{**}$ | | | | 19.25$^{***}$ | | | R=1$^{**}$ | 3.72 | | | 17.35$^{***}$ | 11.74$^{***}$ | |
| | | 17.54$^{***}$ | | | | 0.68 | | | | 4.99$^{**}$ | | | 2.87$^{*}$ | 0.01 | |
| IDR VND | P=2 | | 15.09$^{***}$ | | | 3.43$^{*}$ | | SGD VND PHP | P=6 | 8.64$^{***}$ | | | | 1.08 | 3.50$^{*}$ |
| | R=1$^{*}$ | | 3.43$^{*}$ | | | 15.09$^{***}$ | | | R=1$^{**}$ | 7.85$^{**}$ | | | | 16.81$^{***}$ | 15.59$^{***}$ |
| | | | 4.04$^{**}$ | | | 11.10$^{***}$ | | | | 6.67$^{***}$ | | | | 2.01 | 0.58 |
| MYR PHP | P=7 | | | | 2.07 | | 4.31$^{**}$ | IDR VND PHP | P=7 | | 15.75$^{***}$ | | | 4.40$^{**}$ | 1.88 |
| | R=1$^{*}$ | | | | 4.31$^{**}$ | | 2.07 | | R=1$^{***}$ | | 7.44$^{**}$ | | | 21.56$^{***}$ | 22.17$^{***}$ |
| | | | | | 2.14 | | 0.84 | | | | 0.03 | | | 17.60$^{***}$ | 3.99$^{**}$ |
| SGD IDR THB | P=8 | 34.45$^{***}$ | 0.13 | 22.94$^{***}$ | | | | SGD IDR THB MYR | P=5 | 9.54$^{***}$ | 3.15$^{*}$ | 17.17$^{***}$ | 9.73$^{***}$ | | |
| | R=1$^{***}$ | 22.98$^{***}$ | 37.02$^{***}$ | 35.81$^{***}$ | | | | | R=1$^{***}$ | 23.11$^{***}$ | 27.29$^{***}$ | 30.08$^{***}$ | 29.49$^{***}$ | | |
| | | 32.31$^{***}$ | 3.75$^{**}$ | 5.08$^{**}$ | | | | | | 12.57$^{***}$ | 10.37$^{***}$ | 4.26$^{**}$ | 0.04 | | |

Appendix 1(2). Chi-Square Tests (cont'd)

| Combination | | SGD | IDR | THB | MYR | VND | PHP | Combination | | SGD | IDR | THB | MYR | VND | PHP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SGD IDR | P=5 | 7.03$^{***}$ | 0.59 | | | 1.18 | 5.08$^{**}$ | IDR MYR | P=5 | | 2.89$^{*}$ | | 0.06 | 5.80$^{**}$ | 1.76 |
| VND PHP | R=1$^{*}$ | 14.51$^{***}$ | 13.42$^{***}$ | | | 17.74$^{***}$ | 17.34$^{***}$ | VND PHP | R=1$^{***}$ | | 18.33$^{***}$ | | 19.67$^{***}$ | 7.52$^{*}$ | 12.37$^{***}$ |
| | | 5.72$^{**}$ | 1.34 | | | 0.29 | 3.20$^{*}$ | | | | 0.70 | | 0.02 | 6.65$^{***}$ | 2.59 |
| SGD THB | P=5 | 13.00$^{***}$ | | 12.14$^{***}$ | 11.17$^{***}$ | 13.35$^{***}$ | | SGD IDR | P=4 | 7.27$^{***}$ | 0.00 | 4.60$^{**}$ | 0.47 | 9.56$^{***}$ | |
| MYR | R=2$^{*}$ | 12.99$^{***}$ | | 12.72$^{***}$ | 18.10$^{***}$ | 11.38$^{***}$ | | THB MYR | R=1$^{*}$ | 25.00$^{***}$ | 27.25$^{***}$ | 32.11$^{***}$ | 36.54$^{***}$ | 14.14$^{***}$ | |
| VND | | 8.10$^{**}$ | | 10.98$^{***}$ | 8.05$^{**}$ | 3.32 | | VND | | 1.34 | 3.98$^{**}$ | 1.45 | 8.20$^{***}$ | 2.44 | |
| IDR THB | P=5 | | 0.80 | 1.67 | 0.19 | 5.26$^{**}$ | | SGD IDR | P=5 | 6.28$^{**}$ | 1.90 | 7.53$^{**}$ | | 11.61$^{***}$ | 10.89$^{***}$ |
| MYR | R=1$^{*}$ | | 16.33$^{***}$ | 12.44$^{***}$ | 17.46$^{***}$ | 3.08 | | THB VND | R=2$^{*}$ | 13.70$^{***}$ | 12.48$^{***}$ | 15.05$^{***}$ | | 17.73$^{***}$ | 17.11$^{***}$ |
| VND | | | 2.06 | 0.00 | 0.50 | 4.78$^{**}$ | | PHP | | 5.65$^{*}$ | 1.24 | 0.59 | | 9.93$^{***}$ | 4.26 |

Note: P denotes lag order, and R denotes number of cointegration relationships. SGD denotes the Singapore dollar, IDR denotes the Indonesian rupiah, THB denotes the Thai baht, MYR denotes the Malaysian ringgit, VND denotes the Vietnamese dong, and PHP denotes the Philippine peso.

In each combination, the first row gives the test statistics for "data series are not included in the long-term equilibrium relationships," the second row gives the test statistics for "data series that are included in the cointegration system satisfy the property of stationarity, but the property of stationarity does not relate to other cointegration vectors," and the third row gives the test statistics for "data series that are included in the cointegration system have the property of weak exogeneity over the long run."

*** denotes significance at the 1% level.

** denotes significance at the 5% level.

* denotes significance at the 10% level.

Source: RIETI Discussion Paper Series 12-E-078.

Author's calculation.