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# The Asian Currency Unit, Deviation Indicators, and Exchange Rate Coordination in East Asia: A Panel-Based Convergence Approach

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**Abstract**

Employing the panel convergence method of Phillips and Sul (2007) to the nominal deviation indicators of two recent unofficial constructions of the Asian Currency Unit (ACU) index, this paper examines the existence and extent of convergence in the movements of East Asian currencies against the ACU. Empirical results reveal that intra-East Asian exchange rate movements have not converged to form a cohesive, unified bloc where currencies share homogenous movements, regardless of whether one examines the data on intra-East Asian exchange rate movements before or after the collapse of Lehman Brothers in September 2008. Instead, a separate number of convergent clubs or blocs in the region have formed in recent years. Finally, and most importantly, economies in the region are, generally, converging at different speeds to two opposing poles of convergence: groups of relatively depreciating currencies, and groups of relatively appreciating currencies.

**JEL Classification:** F31, F36, C33

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# 1. INTRODUCTION

Over the last 25 years, regional trade and investment have expanded and deepened in East Asia, driven mainly by market forces. These closer financial ties among countries and areas have made the region's economies highly interdependent, making them increasingly affected by shocks that originate from their neighbors. These economies also compete outside of the region; as such, the potential of losing competitiveness always looms large. A beggar-thy-neighbor policy, which can be costly to all of East Asia in terms of large resource reallocations, is a constant prospect (Kawai and Takagi 2012).

Whether the intensifying economic relationships in East Asia are due to economic integration or economic competition, the necessity of exchange rate stability remains paramount.[1] There has been no consensus in the region on exchange rate policy coordination, but several studies have proposed the creation of a basket of appropriately weighted regional currencies, known as the Asian Currency Unit (ACU).

This paper posits that the monitoring of movements of individual currencies in the region relative to the ACU can be undertaken based on the idea of convergence in deviation indicators. These deviation indicators measure the direction (i.e., appreciation or depreciation) and magnitude of movements of individual currencies relative to the ACU. Convergence in the deviation indicators provides information on a specific group of convergent countries and/or areas whose currencies either collectively appreciate or depreciate relative to the ACU regional average. It follows, therefore, that currencies that belong to the same convergent group have relatively stable bilateral exchange rates, regardless of a stable regional exchange rate.

It can be argued that it is more convenient to examine the deviation indicators based on the US dollar rather than on the ACU. However, the ACU allows observation of a currency's movement relative to the regional average, helping understand issues in a regional dimension (e.g., the relative competitiveness of exports within the region). In addition, the US dollar limits understanding of situations where, for instance, two currencies are both depreciating against the US dollar, yet at the same time, are both appreciating against the ACU. It would not be possible, for example, to capture the two currencies' loss of competitiveness in exports relative to other East Asian countries and/or areas.

To examine the convergence in the deviation indicators, the recently developed panel convergence method of Phillips and Sul (2007) was employed with two alternative deviation indicators calculated using two recent unofficial constructions of the ACU in East Asia. The advantages that this convergence test offers are

(i) based on a time-varying factor model, the test does not demand assumptions regarding the stationarity of the variables and allows for individual series to be transitionally divergent, enabling the test to accommodate long-run equilibrium within a heterogeneous panel, outside of the co-integration setup;

(ii) this test can cluster panel currencies into convergent subgroups (i.e., clubs) when the whole-panel convergence is absent, enabling it to

[1] This argument is supported by several empirical studies, which demonstrated that intraregional exchange rate volatility harms East Asian bilateral trade, e. g., Thorbecke (2008) and Hayakawa and Kimura (2009).

detect whether any specific subgroups of currencies are converging or diverging as well as information on the speed of convergence for each group; and

(iii) it provides information on relative transition parameters for each currency, which can be used to portray each currency and each group's behavior relative to the panel cross-section average over time.

Convergence in the deviation indicators can provide policy makers a dynamic picture of exchange rate movements in the region, helping them carry out effective exchange rate coordination. In the long term, it can also facilitate the formation of subregional currency blocs in which currencies in the region that have shown relative bilateral exchange rate stability due to sufficient convergence in the deviation indicators can approach monetary integration.

Convergence in deviation indicators of currencies in East Asia relative to a regional currency basket has not been previously examined. The only related studies are by Ogawa and Yoshimi (2009) and Ogawa and Wang (2013), both using traditional beta and sigma convergence tests. These found that the deviations of currencies in East Asia relative to the ACU benchmark widened from 2005 to early 2009, and from 2005 to early 2010. Thus, this paper is a fresh contribution to the literature on monetary and financial integration in East Asia, in general, and to the issue of relative exchange rate movements in the region, in particular.

# 2. CONSTRUCTION OF AN ASIAN CURRENCY UNIT INDEX AND DEVIATION INDICATORS

As the ACU is a weighted average of the values of currencies of a group of countries and/or areas in East Asia, it was calculated as

$$ACU_t = \sum_{i=1}^{n} w_i \cdot FX_{i,t} \qquad (1)$$

where $w_i$ and $FX_{i,t}$ represent the weight of currency *i* and the exchange rate against the numeraire currency, typically the US dollar, of currency *i*. For weight calculation, a measure of economic size was used; as such, weights based on indicators such as gross domestic product (GDP) and trade volume share are standard.[2] The base year was chosen when a fundamental equilibrium of both the internal and external sectors is achieved. However, since it is difficult to determine the internal equilibrium of a country or area, the base year was chosen when a measure of the total external transactions of countries and/or areas is as close to being balanced as possible.

## 2.1 RIETI and Hitotsubashi University Construction

Ogawa and Shimizu (2005) suggested the construction of an ASEAN+3[3] regional currency basket like the European Currency Unit, calculating the weights of ASEAN+3 currencies as an arithmetic average of the countries and areas' respective shares of purchasing power parity (PPP)-based GDP and foreign trade.

The base year (i.e., the benchmark period) is chosen when the total trade balance of the countries and areas comprising the currency basket (i.e., the intraregional trade

[2] In the subsection that follows, an alternative approach is presented that avoids the calculation of the basket weights based on standard economic indicators.

[3] ASEAN+3 denotes the Association of Southeast Asian Nations, which includes Brunei Darussalam, Cambodia, Indonesia, the Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam, plus the People's Republic of China, Japan, and the Republic of Korea.

balance), total trade balance of the countries and areas comprising the currency basket with Japan, and total trade balance with the rest of the world are zero. Based on this criterion, 2000 and 2001 were the base years.

In 2009, under Japan's Research Institute of Economy, Trade and Industry (RIETI) and Hitotsubashi University, a regional currency basket for Chiang Mai Initiative Multilateralization (CMIM) member economies (i.e., ASEAN+3 plus Hong Kong, China) was also calculated from this construction.[4] For this, the CMIM contribution shares of each member economy were used.

## 2.2 Pontines (2013) Construction

In addition, Pontines (2013) created the ACU based on a methodology that estimates optimal currency basket weights in the context of a minimized basket or portfolio of assets expressed in terms of national currencies.[5] This was based on Hovanov, Kolari, and Sokolov (2004), which showed that the values of any given currency (e.g., pound sterling) depend on the chosen base currency (e.g., US dollar, euro, or yen), which create ambiguity in the valuation of a currency, making it difficult to examine the dynamics of the time series of currency values. For example, using the US dollar as a base currency as opposed to yen changes the relationship between the euro and pound sterling. To overcome this base currency problem, they proposed a reduced (to the moment $t_0$) normalized value in exchange of *i*-th currency:

$$\mathrm{RNVAL}_i(t/t_0) = \frac{c_{ij}(t)}{\sqrt[n]{\prod_{k=1}^{n} c_{kj}(t)}} \Bigg/ \frac{c_{ij}(t_0)}{\sqrt[n]{\prod_{k=1}^{n} c_{kj}(t_0)}} = \sqrt[n]{\prod_{k=1}^{n} \frac{c_{ik}(t)}{c_{ik}(t_0)}} \tag{2}$$

where $c_{ij}(t)$, $i,j = 1, \ldots, n$, are cross-currencies of exchange rates of $n$ currencies at the moment $t$. Through division by the geometric mean of a basket of currencies, the value of any currency remains the same regardless of the base currency chosen.

This reduced normalized value in exchange ($\mathrm{RNVAL}_i(t/t_0)$) of a currency is useful for comparing the movements of individual currencies and basket currencies. Further, it also allows the computation of a unique, optimal, minimum-variance currency basket regardless of the base currency. The derivation of this minimum variance currency basket was calculated by the optimal weight vector $w^*$ that solves the following optimal control problem:

$$Min\left( S^2(w) = \sum_{i,j=1}^{n} w_i w_j \mathrm{cov}(i,j) = \sum_{i=1}^{n} w_i^2 s_i^2 + 2\sum_{\substack{i,j=1 \\ i<j}}^{n} w_i w_j \mathrm{cov}(i,j) \right) \tag{3}$$

[4] For more information on the construction of the ACU index comprising the CMIM member economies, see RIETI. Newly Organized Data of the Asian Monetary Unit Based on the Contribution Proportion of the CMIM. http://www.rieti.go.jp/users/amu/en/cmi.html (accessed 15 October 2014).

[5] See, also, Pontines and Rajan (2008) and Pontines (2009).

under the constraints $w_i \geq 0,$ for all $i$ = 1, . . . , $n$, $w_1$ + . . . + $w_n$ = 1, where cov($i$,$j$) is the covariance between RNVAL$_i$($t$/$t_0$) and RNVAL$j$($t$/$t_0$), and $s_i^2$ is the variance of RNVAL$_i$($t$/$t_0$) for all $i$,$j$ = 1, . . . , $n$ and all $t$ = 1, . . . , $T$.[6] The optimal weights can also be transformed into optimal currency amounts $q_1^*, q_2^*, \ldots, q_n^*$ as follows:

$$q_i^* = \frac{w_i^* \sum_{r=1}^{n} q_r c_{rj}(t)}{c_{ij}(t)}, \qquad \text{Let} \quad \mu = \sum_{r=1}^{n} q_r c_{rj}(t), \quad \text{thus} \quad q_i^* = \frac{w_i^* \mu}{c_{ij}(t)} \tag{4}$$

Here, the positive factor $\mu$ can be solved with the identification of the optimal weights $w_1^*, w_2^*, \ldots, w_n^*$ derived from the minimization of the variance in equation (2), and $c_{1j}(t)$, $c_{2j}(t)$, . . ., $c_{nj}(t)$. Substituting $\mu$ into equation (4), the optimal currency amounts $q_1^*, q_2^*, \ldots, q_n^*$ were obtained, which constitute the minimum-variance currency basket.

Since a basket or portfolio of assets expressed in terms of national currencies were minimized, the currency weights were determined by two factors: the variance of the reduced normalized value in exchange (RNVAL$_i$($t$/$t_0$)) of the national currencies included in the currency basket, and the covariance of the reduced normalized value in exchange (RNVAL$_i$($t$/$t_0$)) of the national currencies included in the currency basket, and, hence, their correlations.

Thus, the major difference between the Pontines (2013) and RIETI and Hitotsubashi University constructions is that Pontines (2013) avoids the arbitrary choice of economic variables or indicators used to calculate currency weights.

## 2.3 Deviation Indicators

Ogawa and Shimizu (2005) proposed the calculation of deviation indicators, which measure the deviation in each currency included in the currency basket from the benchmark period exchange rate, and with respect to the ACU:

$$The\ Deviation\ Indicator\ (\%) = -\frac{(National\ Currency\ per\ ACU)^{Actual} - (National\ Currency\ per\ ACU)^{Benchmark}}{(National\ Currency\ per\ ACU)^{Benchmark}} \times 100 \tag{5}$$

This measures the relative value for each currency included in the currency basket against all other currencies comprising the ACU, which serves as the regional benchmark. According to equation (5), a positive value of the indicator suggests appreciation of the national currency against the ACU relative to its benchmark value. Based on the two constructions of the ACU, two sets of deviation indicators were calculated using equation (5).

[6] The optimal weights that minimize the variance of a currency basket can be computed using familiar optimization methods for diversifying a portfolio of assets. See Hovanov, Kolari, and Sokolov (2004) for details.

# 3. METHODOLOGY: THE PHILLIPS AND SUL (2007) CONVERGENCE TEST

Standard unit-root and co-integration tests can reject long-run equilibrium because of the short time span of data in which two series can be converging in the long term but the speed of convergence is not fast enough in the given sample period or the speed of convergence is different. The Phillips and Sul (2007) method, however, can detect convergence in these two cases, as it is based on a time-varying factor representation. Specifically, using common stochastic trends, the time-varying factor model can accommodate long-term co-movement in aggregate behavior outside of the co-integration framework and allows for the modeling of transitional effects. Idiosyncratic factor loadings allow for individual heterogeneity and a period of transition in a path that is ultimately governed by a common long-run stochastic trend.

By using the time-varying factor model, the Phillips and Sul (2007) method is more powerful than the traditional beta and sigma convergence tests. In particular, in addition to revealing the speed of convergence for the full panel, it also highlights the different extent and speed of the convergence in the subgroups of members through its club formation procedure.

## 3.1 Convergence of Factor Loadings

A simple single factor model was considered:

$$X_{it} = \delta_i \mu_t + \epsilon_{it}, \tag{6}$$

where $\delta_i$ measures the idiosyncratic distance between a common factor $\mu_t$, and the systematic part of the panel data $X_{it}$ and $\epsilon_{it}$ stands for unit-specific idiosyncratic components.

Phillips and Sul (2007) proposed the new time-varying loading factor representation:

$$X_{it} = \delta_{it} \mu_t, \tag{7}$$

where $\delta_{it}$ is a time-varying factor-loading co-efficient. They further allow $\delta_{it}$ to absorb $\epsilon_{it}$ and to have convergence behavior over time in relation to the common factor $\mu_t$. Specifically, $\delta_{it}$ is modeled in a semiparametric form, implying nonstationary transitional behavior in the following manner:

$$\delta_{it} = \delta_i + \sigma_i \xi_{it} L(t)^{-1} t^{-\alpha}, \tag{8}$$

where $\delta_i$ is fixed, $\xi_{it}$ is *iid*(0, 1) across $i$ but weakly dependent over $t$, and $L(t)$ is a slowly varying function (e.g., $\log\ t$ ) for which $L(t) \to \infty$ as $t \to \infty$.

Equation (8) ensures that $\delta_{it}$ converges to $\delta_i$ for all $\alpha \geq 0$, which therefore becomes a null hypothesis of interest for a cross-section unit. For a panel, the corresponding null hypothesis becomes $\delta_{it} \to \delta$ for some $\delta$, as $t \to \infty$ and $\alpha \geq 0$.

## 3.2 Relative Transition

To obtain information about the time-varying factor loading $\delta_{it}$, Phillips and Sul (2007) employed the relative version of $\delta_{it}$, the relative-loading factor or the relative-transition parameter, as follows:

$$h_{it} = \frac{X_{it}}{\frac{1}{N}\sum_{i=1}^{N} X_{it}} = \frac{\delta_{it}}{\frac{1}{N}\sum_{i=1}^{N} \delta_{it}}, \tag{9}$$

where $h_{it}$ is the relative transition parameter that measures $\delta_{it}$ in relation to the panel average at time $t$ and therefore describes the transition path for country or area $i$ relative to the panel average.

Given equation (9), the cross-sectional mean of $h_{it}$ is unity. In addition, if the factor-loading coefficients $\delta_{it}$ converge to $\delta$, then the relative transition parameters $h_{it}$ converge to unity. In this case, the cross-sectional variance of $h_{it}$, $H_t$, converges to zero in the long run:

$$H_t = \frac{1}{N}\sum_{i=1}^{N}(h_{it} - 1)^2 \rightarrow 0 \text{ as } t \rightarrow \infty. \quad (10)$$

Equation (10) was used to test the null hypothesis of convergence and to group the East Asian currencies into convergence clusters or clubs.

## 3.3 The *log t* Convergence Test

Phillips and Sul (2007) proposed a simple regression-based testing procedure to examine the null of convergence, $H_0: \delta_i = \delta$ and $\alpha \geq 0$, against the alternative of $H_A: \delta_i \neq \delta$ or $\alpha < 0$.

The procedure involves three steps. First, the cross-sectional variance ratio $H_1/H_t$ is calculated, given that $H_t = \frac{1}{N}\sum_{i=1}^{N}(h_{it} - 1)^2$. Second, the following ordinary least squares regression is run, and a conventional robust $t$ statistics, $t_{\hat{b}}$, is calculated for the coefficient $\hat{b}$ using the estimate of the long-run variance of the regression residuals:

$$log\left(\frac{H_1}{H_t}\right) - 2logL(t) = \hat{a} + \hat{b}log\ t + \hat{u}_t, \quad (11)$$

for $t = [rT], [rT] + 1, \ldots, T$ with some $r > 0$. Phillips and Sul (2007) recommended $r = 0.3$ based on their simulations. Other settings of the regression include $L(t) = log\ (t + 1)$ and the fitted coefficient of $\log t$ is $\hat{b} = 2\hat{a}$, where $\hat{a}$ is the estimate of $a$ under the null.

A one-sided $t$ test of null $\alpha \geq 0$ using $\hat{b}$ is then performed, with a standard error estimated using a heteroskedasticity and autocorrelation consistent estimator. Given that the test statistic $t_{\hat{b}}$ is asymptotically normally distributed, the null of convergence is rejected at the 5% significance level if $t_{\hat{b}} < -1.65$.

Note that $\hat{\alpha} \geq 1$ and, accordingly, $\hat{b} \geq 2$ implies level (i.e., absolute) convergence and that $1 > \hat{\alpha} \geq 0$ and, accordingly, $2 > \hat{b} \geq 0$ implies rate (i.e., conditional) convergence.

## 3.4 Club Convergence and Clustering

Rejection of the null of full-panel convergence does not imply that there is no convergence. There may be one or more convergent clusters as well as divergent units in the panel. Based on repeated log *t* regressions, Phillips and Sul (2007) provided a four-step algorithm to detect such units of clusters:

(i) Panel units $X_{it}$ are ordered according to the last observation, $X_{iT}$.

(ii) The first *k* highest panel units are selected to form subgroup $G_k$ for some $N > k \geq 2$. The convergence test statistic $t_{\hat{b}}(k)$ is calculated for each *k*. The core group size $k^*$ is chosen according to $k^* = argmax_k\{t_{\hat{b}}(k)\}$ subject to $min\{t_{\hat{b}}(k)\} > -1.65$. If $k^* = N$, there is full-panel convergence. If $min\{t_{\hat{b}}(k)\} > -1.65$ does not hold for $k = 2$, the first unit is dropped, and the same procedure performed for the remaining units. If

$min\{t_{\hat{b}}(k)\} > -1.65$ does not hold for every subsequent pair of units, there are no convergent clusters in the panel. In all other cases, a core group can be detected.

(iii) One remaining unit at a time is added to the core group, and the $log\ t$ test is performed. If the corresponding $t$ statistic from this regression, $\hat{t}$, exceeds a chosen critical value, $c$,[7] then the unit is included in the current subgroup. The $log\ t$ test is run for this subgroup, and if $t_{\hat{b}} > -1.65$, the formation of this subgroup is completed. Otherwise, the critical value $c$ must be raised, and the procedure repeated.

(iv) A subgroup of the units is formed for which $\hat{t} < c$ in (iii). The $log\ t$ test is run for this subgroup, and if $t_{\hat{b}} > -1.65$, this cluster converges, and there are two convergent subgroups in the panel. Otherwise, (i)–(iii) must be repeated on this subgroup to determine whether a smaller convergent subgroup exists. If there is no $k$ in (ii) for which $t_{\hat{b}}(k) > -1.65$, the remaining units diverge.

# 4. DATA AND EMPIRICAL RESULTS

For this paper, the Pontines (2013) method was used to construct an optimal ACU index composed of the ASEAN+3[8] currencies as well as that of Hong Kong, China (i.e., the CMIM) using monthly nominal exchange rate data for January 2000–June 2013. The RIETI and Hitotsubashi University approach was then followed to calculate the nominal deviation indicators. Nominal exchange rate data were collected from the International Monetary Fund.[9] Calculated nominal deviation indicators were retrieved from RIETI.[10]

Both sets of deviation indicators calculated from the two constructions of the ACU are illustrated in Figure 1 and Figure 2. In both cases, fluctuations of the deviation indicators start to widen around 2004–2005, further widening since the end of 2008. Overall, both nominal deviation indicators share similar shapes, although Pontines (2013) indicates relatively higher deviations than RIETI and Hitotsubashi University for most currencies since 2003. During 2007–2008, for some currencies, the Pontines (2013) had relatively lower deviations than the RIETI and Hitotsubashi University nominal deviation indicator.

The $log\ t$ convergence and club convergence tests were then applied to both indicators.[11] Following the recommendation by Phillips and Sul (2007), the convergence analysis was conducted on a filtered data series in which the cyclical component of each series was removed by applying the Hodrick-Prescott filter (Hodrick and Prescott 1997). The first four years (2000–2003) were also excluded to eliminate the base-year effect.

[7] Note that, following Phillips and Sul (2009), $c = 0$, as the number of observation is not particularly large.

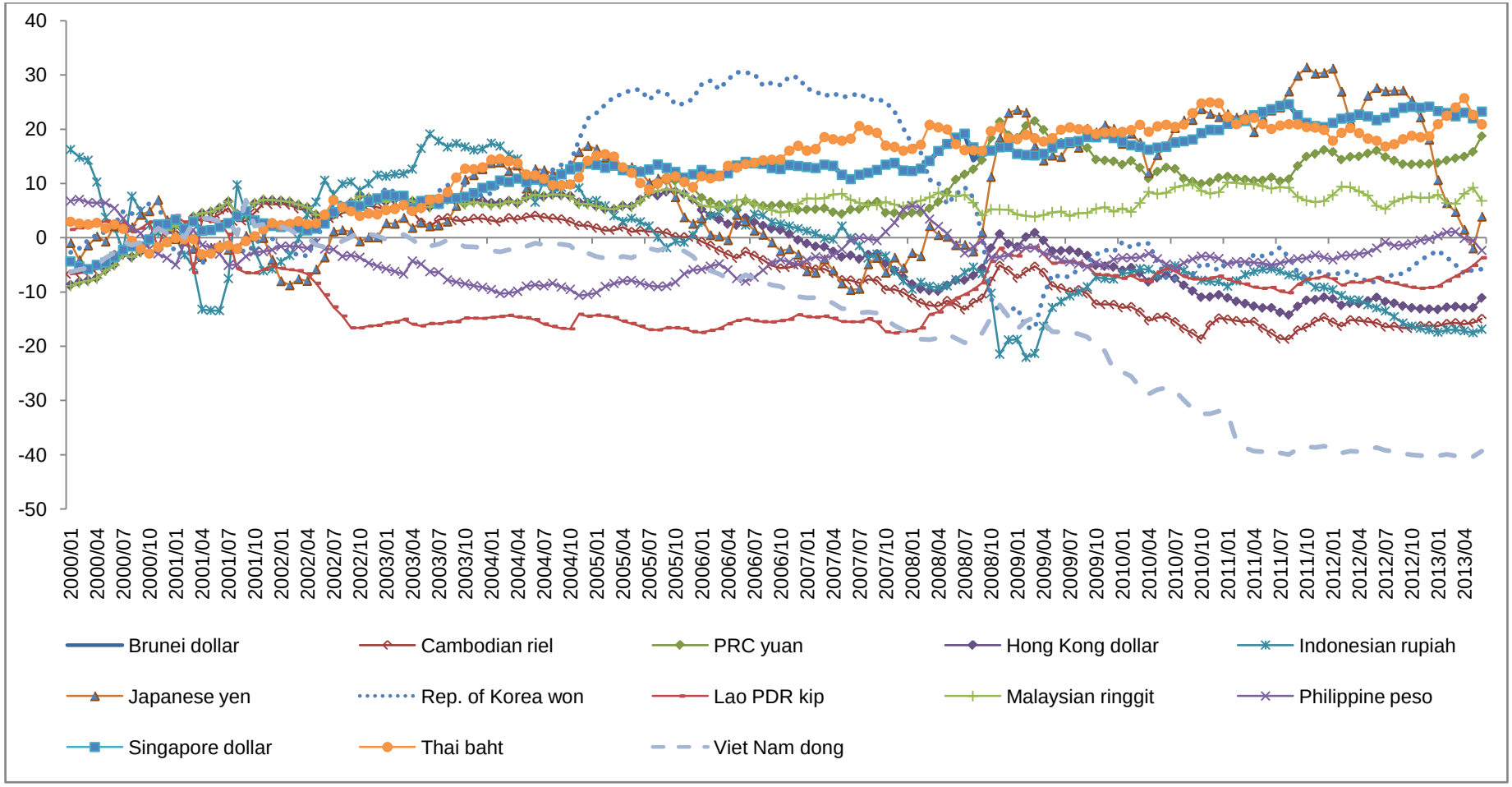
[8] Note that Myanmar is not included in the sample for consistency because the calculated deviation indicators provided by RIETI do not include Myanmar.

[9] International Monetary Fund. International Financial Statistics. http://data.imf.org/?sk=5DABAFF2-C5AD-4D27-A175-1253419C02D1

[10] RIETI. AMU and AMU Deviation Indicators. http://www.rieti.go.jp/users/amu/en/index.html#data (accessed 15 October 2014).

[11] The GAUSS system used to carry out these tests is available at http://www.utdallas.edu/~dxs093000/papers/Recent%20Working%20Papers1.htm

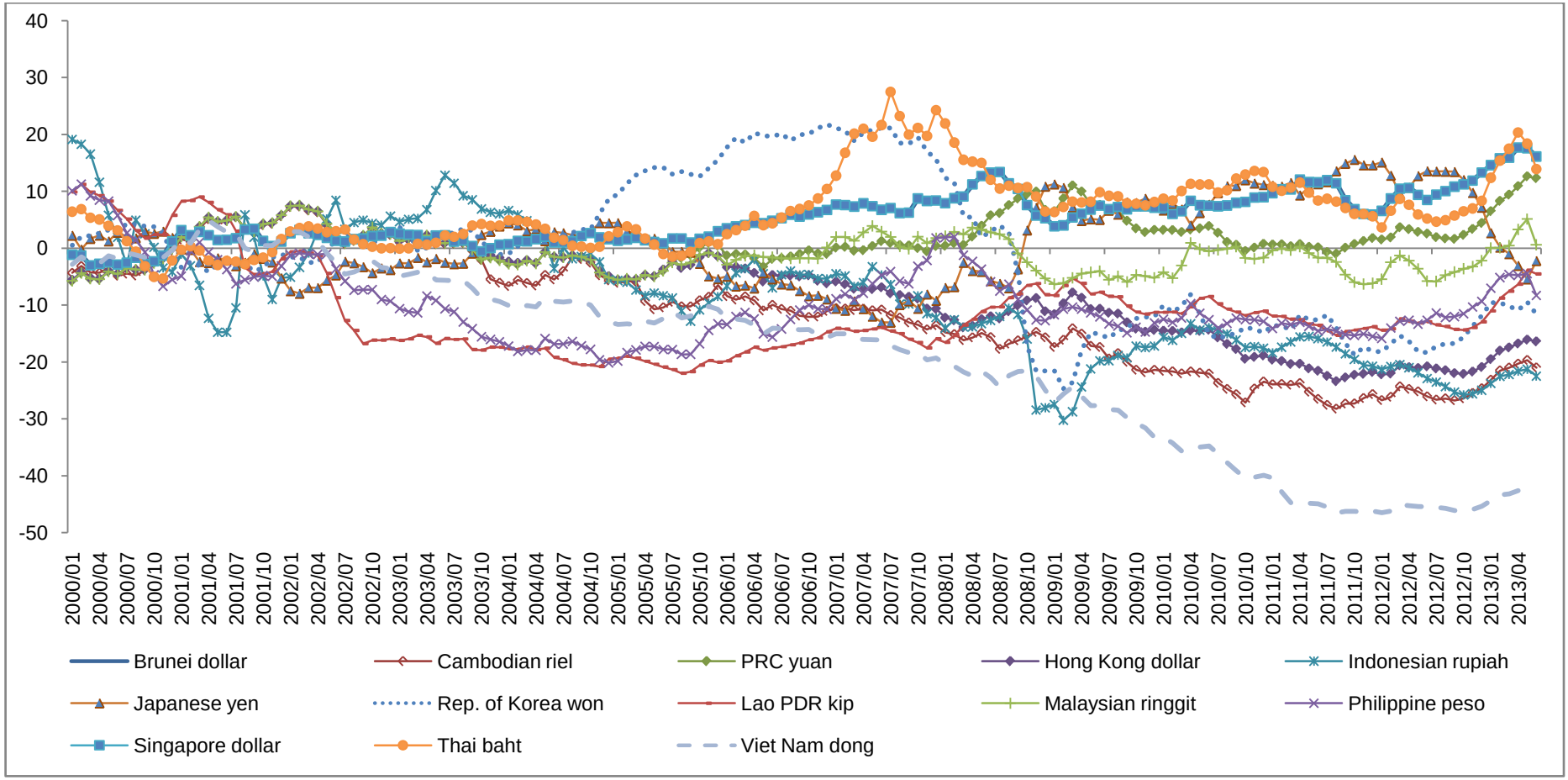
**Figure 1: Pontines (2013) Nominal Deviation Indicator**




Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Source: Authors.

**Figure 2: RIETI and Hitotsubashi University Nominal Deviation Indicator**




Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Source: Authors.

Further, the global financial crisis, which peaked at the end of 2008 due to the collapse of Lehman Brothers, had a profound effect on both developed and developing countries. To examine whether and how the full panel and club convergence process, if present, were affected by the crisis, the sample period was divided around the time Lehman Brothers collapsed in September 2008: pre-crisis, January 2004 to September 2008; and post-crisis, October 2008 to June 2013.[12]

$h_{it}$, the relative transition parameter, describes the transition path for country or area $i$ vis-à-vis the panel average. Correspondingly, the relative transition parameters with the cross-sectional means in each of the convergent club demonstrate one club's behavior in relation to the club average.

The results are first presented according to the Pontines (2013) nominal deviation indicator (Table 1, Figure 3, and Figure 4), and by the results of the convergence tests on the nominal deviation indicator of RIETI and Hitotsubashi University (Table 2, Figure 5, and Figure 6).

**Table 1: The $\log t$ Convergence and Club Convergence Test Results, Pontines (2013) Nominal Deviation Indicators**

| $\log t$ Convergence Tests | | | |
|---|---|---|---|
| January 2004–September 2008 | | October 2008–June 2013 | |
| $\hat{b}: -1.659$ | | $\hat{b}: -1.078$ | |
| $t-stat: -23.321^a$ | | $t-stat: -94.937^a$ | |
| Club Convergence Tests | | | |
| January 2003–September 2008 | | October 2008–June 2013 | |
| Club 1 | Brunei dollar | Brunei dollar | Club 1 |
| $\hat{b}: 1.427$ | Yuan | Singapore dollar | $\hat{b}: 0.552$ |
| $t-stat: 8.493$ | Won | | $t-stat: 1.082$ |
| | Singapore dollar | | |
| | | Yuan | Club 2 |
| Club 2 | Hong Kong dollar | Baht | $\hat{b}: -0.125$ |
| $\hat{b}: 0.332$ | Yen | | $t-stat: -1.434$ |
| $t-stat: 12.842$ | Kip | | |
| | Ringgit | Yen | Club 3 |
| | Peso | Ringgit | $\hat{b}: 0.089$ |
| | | Peso | $t-stat: 1.118$ |
| Club 3 | Riel | Riel | Club 4 |
| $\hat{b}: 1.375$ | Rupiah | Hong Kong dollar | $\hat{b}: 0.521$ |
| $t-stat: 10.344$ | | Rupiah | $t-stat: 2.998$ |
| Divergent | Baht | Won | Divergent |
| $\hat{b}: -2.213$ | Dong | Kip | $\hat{b}: -1.868$ |
| $t-stat: -57.798^a$ | | Dong | $t-stat: -256.937^a$ |

[a] Indicates rejection of the null hypothesis of convergence at the 5% significance level.
Source: Authors' calculations.

[12] In the appendix, the convergence analysis was conducted working with the entire sample period, excluding the period around the time of the collapse of Lehman Brothers. Results were obtained that further reinforce those reported in the main text.

**Table 2: The $\log t$ Convergence and Club Convergence Tests Results, RIETI and Hitotsubashi University Nominal Deviation Indicators**

| $\log t$ Convergence Tests | | | |
|---|---|---|---|
| January 2004–September 2008 | | October 2008–June 2013 | |
| $\hat{b}: -2.026$ | | $\hat{b}: -1.015$ | |
| $t-stat: -22.666^a$ | | $t-stat: -73.411^a$ | |
| Club Convergence Tests | | | |
| January 2003–September 2008 | | October 2008–June 2013 | |
| Club 1 | Brunei dollar | Brunei dollar | Club 1 |
| $\hat{b}: 0.565$ | Yuan | Singapore dollar | $\hat{b}: 1.871$ |
| $t-stat 4.929$ | Won | | $t-stat: 5.986$ |
| | Kip | | |
| | Peso | Yuan | Club 2 |
| | Singapore dollar | Yen | $\hat{b}: 0.027$ |
| | | Baht | $t-stat: 0.162$ |
| Club 2 | Yen | Ringgit | Club 3 |
| $\hat{b}: -0.108$ | Ringgit | Peso | $\hat{b}: -0.030$ |
| $t-stat: -0.049$ | | | $t-stat: -0.559$ |
| Club 2 | Riel | Won | Club 4 |
| $\hat{b}: 1.523$ | Rupiah | Kip | $\hat{b}: -0.037$ |
| $t-stat: 12.620$ | | | $t-stat: -0.168$ |
| Divergent | Hong Kong dollar | Riel | Club 5 |
| $\hat{b}: -2.374$ | Baht | Hong Kong dollar | $\hat{b}: 0.166$ |
| $t-stat: -189.188^a$ | Dong | Rupiah | $t-stat: 1.271$ |
| | | Dong | Divergent |

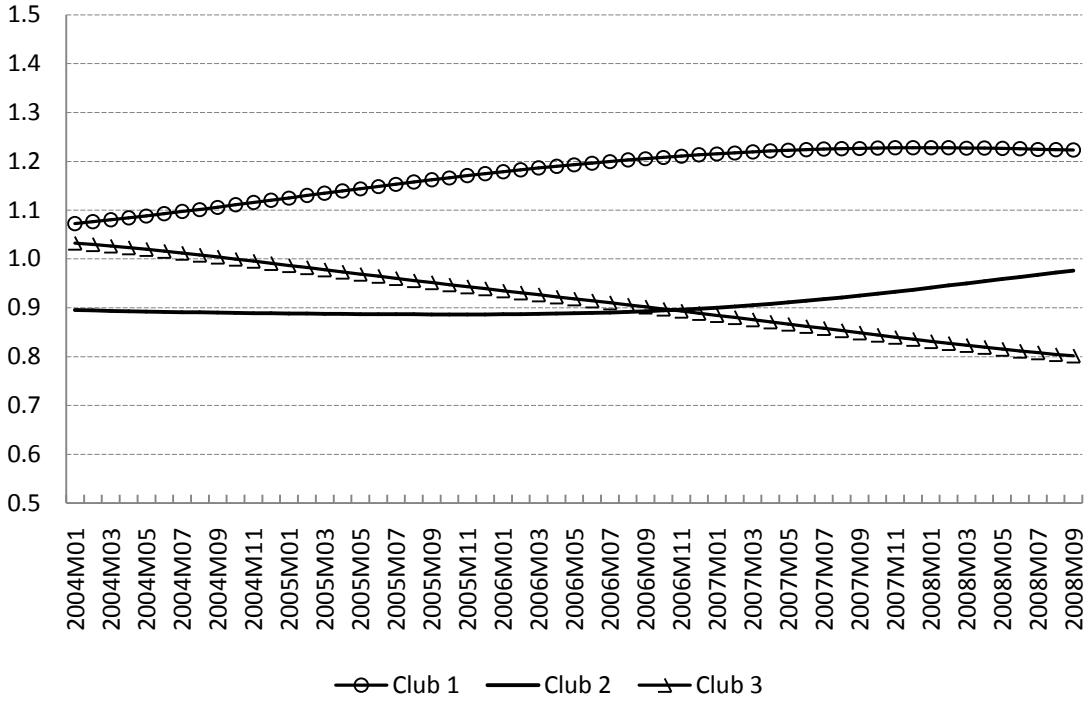
[a] Indicates rejection of the null hypothesis of convergence at the 5% significance level. There are no statistics for the dong during the post-crisis period as Viet Nam is a single divergent country.

Source: Authors' calculations.

The $log\ t$ convergence regression results presented in the upper panel of Table 1 suggest that, since $t_{\hat{b}} < -1.65$, the null of convergence is rejected in both the pre- and post-crisis periods. This implies that there is no full-panel convergence in both subperiods. A full-panel convergence is only possible if the deviation indicators of all currencies moved toward similar values via similar paths. This is clearly not the case, as shown in Figure 3.

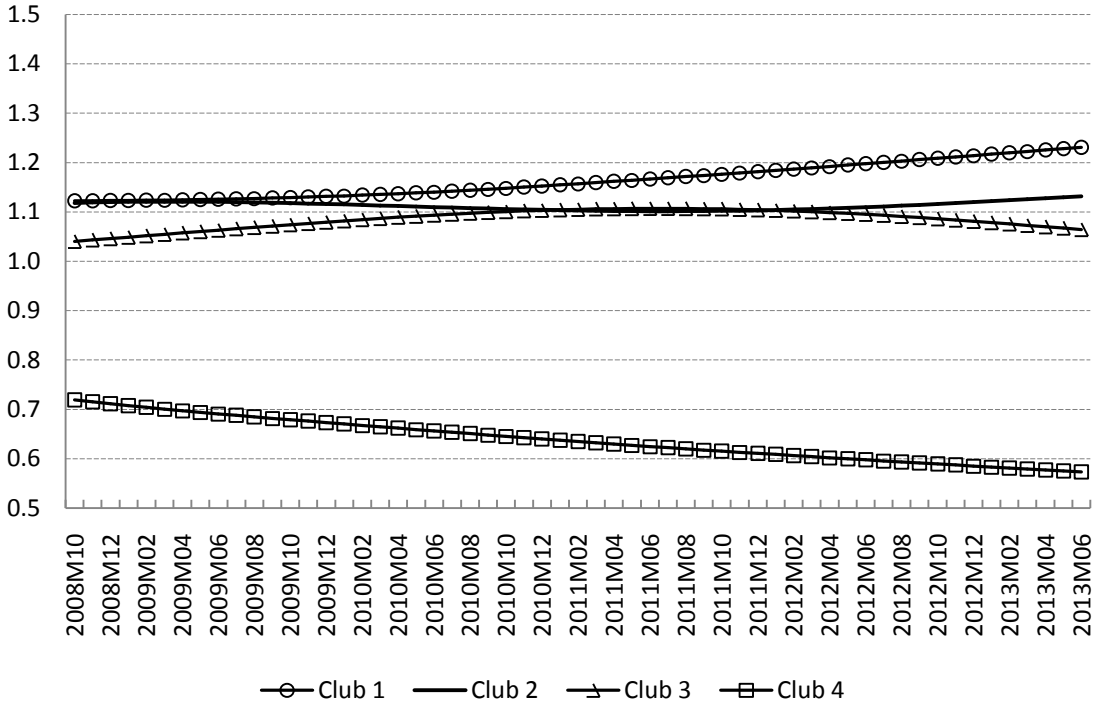
For the pre-crisis period, three convergent clubs are detected. Club 1 includes the Brunei dollar, Singapore dollar, won, and yuan. Club 2 includes the Hong Kong dollar, kip, peso, ringgit, and yen, and club 3 includes the riel and rupiah. The speed of convergence, measured by the value of $\hat{b}$, indicates that clubs 1 and 3 are slightly faster than club 2, although in all three clubs, $\hat{b} < 2$; thus, there is convergence in rates (i.e., conditional convergence) rather than convergence in levels (i.e., absolute convergence).

**Figure 3: Relative Transition Paths across Clubs based on Pontines (2013) Nominal Deviation Indicator, Pre-Crisis**



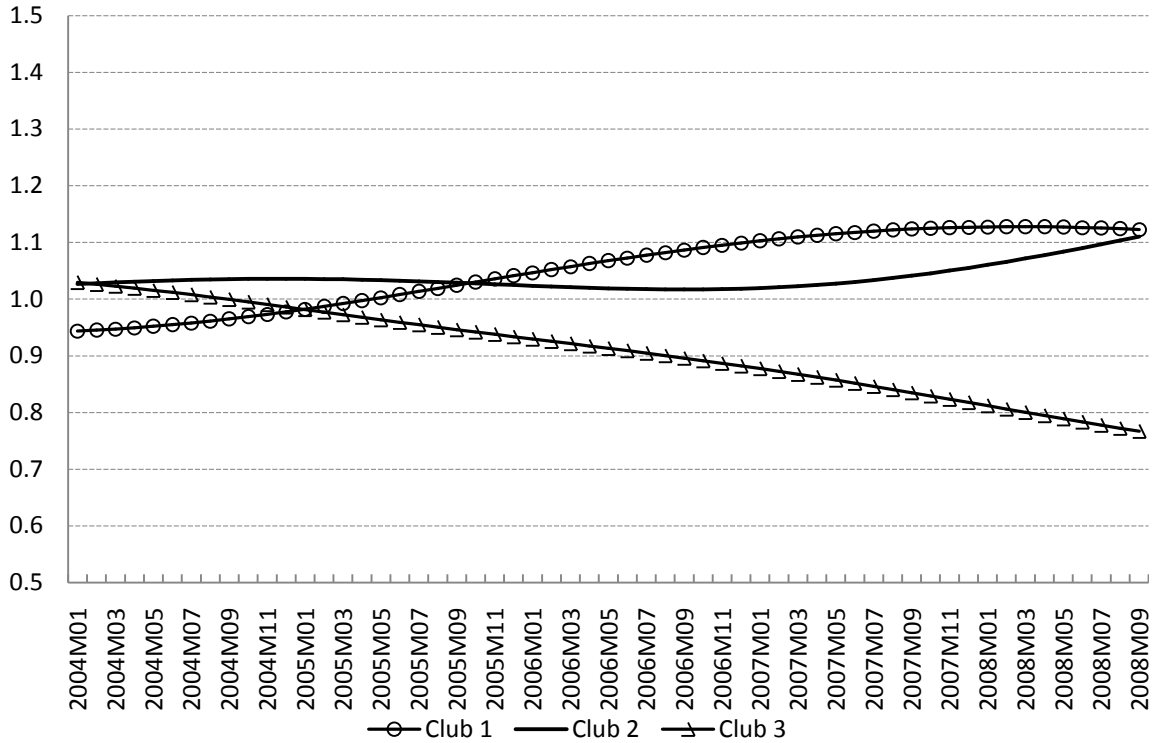

Source: Authors' calculations.

**Figure 4: Relative Transition Paths across Clubs based on Pontines (2013) Nominal Deviation Indicator, Post-Crisis**



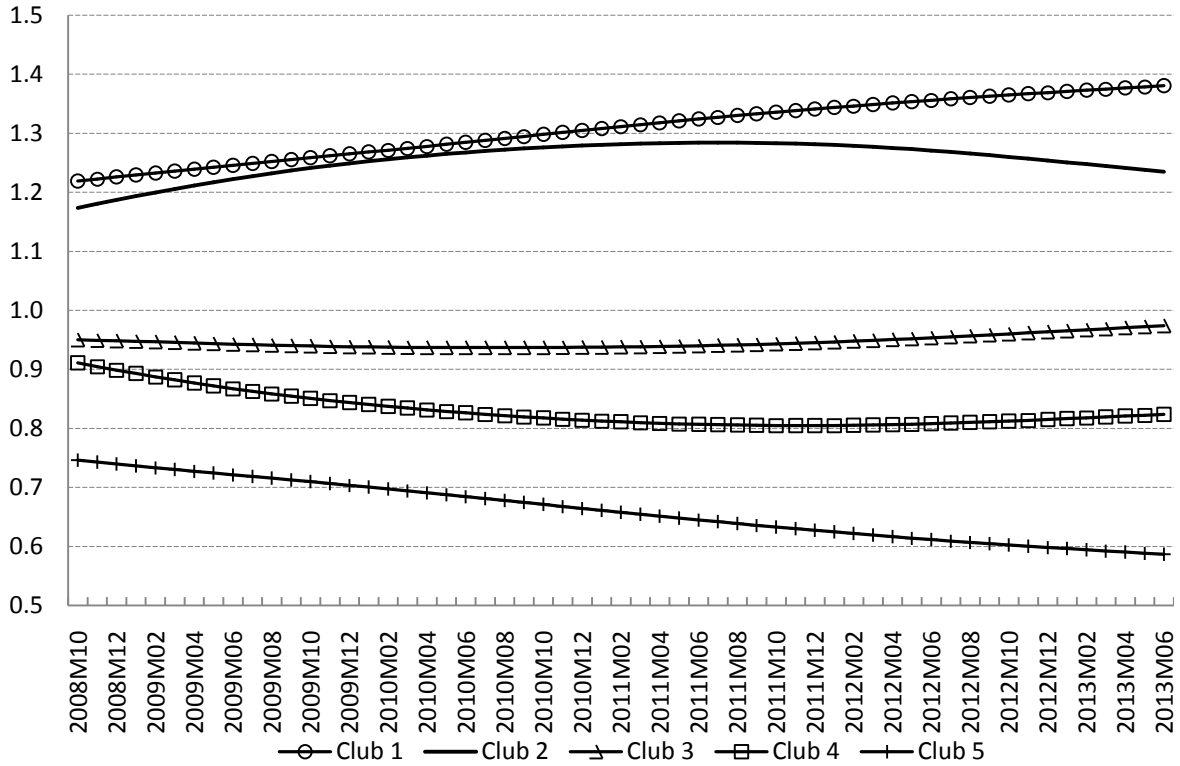

Source: Authors' calculations.

**Figure 5: Relative Transition Paths across Clubs Based on the RIETI and Hitotsubashi University Nominal Deviation Indicator, Pre-Crisis**




Source: Authors' calculations.

**Figure 6: Relative Transition Paths across Clubs Based on the RIETI and Hitotsubashi University Nominal Deviation Indicator, Post-Crisis**




Source: Authors' calculations.

Examining the corresponding club transition paths as indicated by the relative transition parameters in Figure 3,[13] currencies in club 1 appreciate relative to the cross-club mean from the beginning of the sample period until the end of 2007, which until the end of the subsample period experience very moderate depreciation. In contrast, currencies in club 2 slightly depreciate from the beginning of the subperiod until the end of 2005, which then visibly appreciate thereafter at a stronger pace. These two clubs then slowly move toward each other by the time Lehman Brothers collapsed. In terms of club 3, a consistent depreciation is observed relative to the cross-club average, showing no sign of convergence with clubs 1 and 2. There are also two divergent currencies, the baht and dong, which do not belong to any clubs or form a convergent club among the others. A likely explanation is that the dong showed persistent and much faster depreciation than any other panel currency during the pre-crisis period, while the opposite was true for the baht, which showed relatively faster appreciation.

In the post-crisis period, a drastic reconfiguration of convergent clubs is observed. There are now four clubs with different members. Similar to the pre-crisis period, rate (i.e., conditional) convergence is observed rather than level (i.e., absolute) convergence, since in all cases, $\hat{b} < 2$. Moreover, the values of $\hat{b}$ are, in general, lower than those from the pre-crisis period, implying a slower speed of convergence. Among these four clubs, specifically, currencies in clubs 1 and 4 converge moderately faster than the currencies in clubs 2 and 3, given their slightly higher values of $\hat{b}$. Looking at the members in the post-crisis period, the Brunei dollar and Singapore dollar, as in the pre-crisis, are in the same club and have the highest value of $\hat{b}$. The baht, which was divergent in the pre-crisis period due to its faster appreciation relative to other currencies in the group, slows down its appreciation, and then forms a club with the yuan. Meanwhile, the peso, ringgit, and yen remain in the same club, while the Hong Kong dollar joins the riel and rupiah in the same club. Finally, the kip and won join the dong as the three divergent economies in the post-crisis period.

The transition paths of these four clubs are depicted in Figure 4. Interestingly, there are two pairs of clubs that exhibit opposite transition paths in the post-crisis period. For instance, currencies in club 1 (i.e., the Brunei dollar and Singapore dollar) and club 4 (i.e., the Hong Kong dollar, riel, and rupiah) converge within the clubs at almost the same speed as indicated by their similar values of $\hat{b}$ in Table 1, but show opposite directions of persistent appreciation and depreciation, respectively, relative to the cross-club average. Meanwhile, club 2 (i.e., the baht and yuan) and club 3 (i.e., the peso, ringgit, and yen) start with relative depreciation and appreciation, until mid-2011, and then reverse directions. Hence, clubs 2 and 3 are moving toward each other until mid-2011, when they begin to diverge again.

Furthermore, when comparing club 2 with club 1, their transition paths have starting points at similar levels, indicating that their currencies have appreciated relative to other currencies by similar percentages pre-crisis. However, currencies in club 2 initially lose their momentum of relative appreciation immediately after the peak of the crisis before they start to appreciate again toward the end of the sample period. Looking at all four transition paths in Figure 4, clubs 1 and 2 both appreciate relative to the club average, although at different paces. Finally, with regard to the three divergent currencies of the dong, kip, and won, the kip and won seem to have their own distinctive transition paths that do not move toward each other nor move together with any other clubs, while the dong continues its much faster depreciation compared to any other panel members.

[13] To save space, individual transition parameters for each country or area are not provided. These are available upon request.

The club formation process and the corresponding transition paths using the calculated nominal deviation indicator from Pontines (2013) indicate that there are more clubs detected in the post-crisis period than pre-crisis, and there are significant changes in terms of club membership between these periods. The crisis sent an adverse shock to Asian currencies, and the reaction among these countries and areas was to form new clubs that behave in a less collective manner. Specifically, while club 1 and club 2 in Figure 3 show signs of convergence toward each other pre-crisis, during the post-crisis period, a more divergent picture emerges, particularly, about 3 years after the peak of the crisis.

In terms of the behavior of individual currencies, two pairs tend to stand out: the Brunei dollar and Singapore dollar, and the riel and rupiah. These have always belonged to the relative appreciation and depreciation clubs, respectively. The dong is divergent throughout both subperiods.

The $log\ t$ convergence and club convergence tests results for the nominal deviation indicators calculated from RIETI and Hitotsubashi University are presented in Table 2, and the corresponding club transition paths in figures 5 and 6. Looking at the $log\ t$ convergence test results in the upper panel of Table 2, the null of full-panel convergence is rejected for both sample periods. This is the same finding obtained using the nominal deviation indicators calculated from Pontines (2013) in Table 1. Moreover, given that $\hat{b} < 2$, the club convergence test results for both sample periods suggest rate (i.e., conditional) rather than level (i.e., absolute) convergence in all clubs detected, which is also in line with the findings in Table 1.

The club convergence test results for the pre-crisis period suggest that there are also three convergent clubs, although there are clear differences in terms of club membership between tables 1 and 2 during this period. For instance, the kip and peso, two currencies that originally belong to the second club in Table 1, now join the first club, which is composed of the Brunei dollar, Singapore dollar, won, and yuan. The Hong Kong dollar, which belongs to the second club in Table 1, is now in a divergent economy. The baht, along with the dong, are divergent in the pre-crisis period, irrespective of the nominal deviation indicators used to construct the ACU index. Moreover, each of these currency pairs belongs to the same club in both tables 1 and 2: the ringgit and yen (club 2), and the riel and rupiah (club 3).

In the corresponding club transition paths for the pre-crisis period (Figure 5), although club 3 maintains similar level and shape when compared to the same club in Figure 3, clubs 1 and 2 in Figure 5 behave differently as compared to the same clubs in Figure 3. Specifically, the starting and ending points of the transition path of club 1 in Figure 5 is relatively lower compared to the one in Figure 3, whereas the transition path of club 2 varies from appreciation to depreciation and back throughout the pre-crisis period. This is a reflection of the cross-club shifts earlier observed in tables 1 and 2 in the case of the kip and peso as well as the exclusion of the Hong Kong dollar from the convergent clubs in Table 2.

During the post-crisis period, according to the nominal deviation indicators from RIETI and Hitotsubashi University, the club convergence tests suggest one additional convergent club in Table 2 compared to Table 1, making a total of five clubs instead of four. Comparing club membership between tables 1 and 2, the yen moves from club 3 to club 2 to join the baht and yuan, while the kip and won, two currencies that are divergent currencies in Table 1, now form the additional club. Apart from these differences, members of club 1 and club 4 in Table 1 are identical to those of the members in club 1 and club 5 in Table 2. Also, the baht and yuan remain in the same

club, irrespective of alternative indicator used. The same applies to the peso and ringgit. Similar to Table 1, the dong is again divergent.

Examining club transition paths in Figure 6, clubs 1 and 5 share similar shapes as clubs 1 and 4 in Figure 4. However, for clubs 2 and 3 in Figure 6, the shapes of their transition paths seem to have been interchanged with the shapes of the transition paths of the same two clubs in Figure 4. This may reflect the cross-club movement of the yen as reported in Tables 1 and 2.

Overall, some of these systematic patterns are observed at the end of the first and second subperiod as depicted in Figures 3 and 5 and Figures 4 and 6, respectively. First, pre-crisis, signs of convergence across clubs in Figures 3 and 5 (e.g., clubs 1 and 2 in both figures) are evident. However, the convergence process for these two clubs using both indicators are interrupted by the crisis. From thereon, more clubs form, and membership changes between the two periods.

Second, Figure 4 suggests two relatively opposing convergent poles at the very end of the period. Specifically, clubs 1 and 2 move toward the same direction of relative appreciation but at different paces, while clubs 3 and 4 move toward relative depreciation also at different paces. Figure 6 suggests that at the end of the period of observation, clubs 2 and 5 form a pole of relative depreciation, while clubs 1, 3, and 4 form a pole of relative appreciation.

# 5. SUMMARY AND IMPLICATIONS OF THE RESULTS

There is growing recognition in East Asia that excessive intraregional exchange rate volatility can have harmful effects on the ever-closer trade and financial ties among countries and areas in the region. Specifically, excessive intraregional exchange rate volatility can hurt the extent of intra-Asian trade as measured by an average of export and import shares; the related development of intra-Asian supply chains by multinational corporations since the early 1990s, which has given rise to a growing intensity of vertical intra-industry trade in the region (Chow et al. 2010); and the rising intensity of foreign direct investment flows among countries and areas. Thus, in view that exchange rates form a vital link in the growing interdependence among East Asian countries and areas, working towards regional exchange rate coordination can help achieve intraregional exchange rate stability.

The evidence provided in this paper indicates that the state of play in relative exchange rate movements within the region is complex; as such, achieving the worthwhile objective of exchange rate stability in East Asia will be difficult.

Intra-East Asian exchange rate movements have not converged to form one, cohesive bloc in which currencies share homogenous movements, regardless of whether one examines data on intra-East Asian exchange rate movements before or after the collapse of Lehman Brothers in September 2008. There is a sufficient amount of heterogeneity in bilateral East Asian exchange rate movements that hinder the economies in the region from forming a unified exchange rate bloc. Instead, a certain separate number of convergent clubs in the region have formed in recent years, of which the number and composition vary, depending on which measure of the nominal deviation indicator of the ACU is used as well as on the period that the data are examined.

Economies in the region are, generally, converging at different speeds to two opposing poles of convergence, i.e., groups of relatively depreciating currencies, and groups of relatively appreciating currencies. While this is beyond the scope of this paper, these

two opposing poles of convergence can be driven by real and monetary factors such as the relative competitive positions of countries and areas in the region, differing growth rates, diverging fiscal balances, as well as the varying extent of monetary policy stances and regimes.[14] The values and convergence of the nominal deviation indicators should be studied in the future.

An intraregional deviation indicator convergence occurring at different speeds and at two opposing poles of trajectories is altering competitive trading relationships in the region. For instance, Japanese companies are relocating their manufacturing production bases from the People's Republic of China to other locations in Asia.[15] In the long term, countries and areas in the region can take a multitrack or multispeed approach, in which those that have shown relative bilateral exchange rate stability due to the achievement of sufficient convergence in the deviation indicators and real convergence can begin the process of a formal exchange rate arrangement. Any subregional currency arrangements formed can then eventually be linked into a wider regional monetary zone.

# 6. CONCLUSION

This paper examined the existence and extent of convergence in deviation indicators in the ASEAN+3 economies as well as Hong Kong, China. To do so, the recently developed panel convergence method of Phillips and Sul (2007) was used to identify the nominal deviation indicators of two recent unofficial constructions of the ACU to detect convergence in the exchange rate movements in these economies. The advantage of this time-varying factor model is that it uses common stochastic trends that can accommodate long-run co-movement in aggregate behavior outside of the co-integration framework and modeling of transitional effects. Further, the method is more powerful than the traditional beta and sigma convergence tests since not only it reveals the speed of convergence for the full panel, but highlights the different extent and speed of the convergence in the subgroups of members through its club formation procedure.

Empirical results reveal that intra-East Asian exchange rate movements have not converged to form one, unified currency bloc, regardless of whether one examines the data on intra-East Asian exchange rate movements before or after the collapse of Lehman Brothers in September 2008. Rather, a certain separate number of convergent clubs or blocs in the region have formed, of which the number and composition vary, depending on which measure of the nominal deviation indicator of an ACU is used, as well as the period the data are examined. Economies in the region are, generally, converging at different speeds to two opposing poles of convergence: groups of relatively depreciating currencies, and groups of relatively appreciating currencies.

Despite important strides achieved by the region in financial cooperation and given the critical role of the exchange rate in the ongoing process of economic integration, there has been limited progress in exchange rate policy cooperation. One way to move forward is the adoption and calculation of ACU-based nominal deviation indicators, which can provide policy makers a useful monitoring and surveillance device of the

[14] See, for example, You and Sarantis (2011, 2012a, 2012b) for incorporating a range of economic fundamentals into alternative exchange rate models to determine the value of the yuan.

[15] See, for example, Ito and Shimizu (2009). For more examples of deconcentration of production bases, see PriceWaterhouseCoopers. 2007. *Vietnam's Automotive Component Industry: Ready to Go Global?* Ho Chi Minh City; and A. Sharp. 2012. Nissan Ships Cars Home as Yen Erodes Century of Made-in-Japan. *Bloomberg Business.* 30 August.

movements in intra-East Asian exchange rates. Specifically, convergent groups in the region and their relative transition paths provide an illustration on how such nominal deviation indicators can assist in the efficient monitoring of movements in relative exchange rates in East Asia over time. However, policy makers must be made aware of the distinguishing features and limitations of such ACU-based nominal deviation indicators in exchange rate surveillance work. The number and composition of convergence clubs vary depending on which ACU-based nominal deviation indicator used, so a strategy of employing alternative versions of ACU-based nominal deviation indicators in assessments of exchange rate convergence is prudent.

In the near term, adopting such an approach can be facilitated by the inclusion of an ACU-based nominal deviation indicator convergence analysis in surveillance reports submitted to senior finance and central bank officials in ASEAN+3. This should contribute to open, candid discussions. Once sufficient confidence is built into this process, economies in the ASEAN+3 region can better understand the benefits of any subregional exchange rate arrangement, which can then facilitate the achievement of intraregional exchange rate stability and more formal forms of exchange rate coordination in the wider East Asian region.

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* The Asian Development Bank refers to China by the name People's Republic of China.

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# APPENDIX: CONVERGENCE TESTS FOR THE ENTIRE SAMPLE PERIOD EXCLUDING THE PERIOD OF THE LEHMAN BROTHERS COLLAPSE

Six months before and six months after the September 2008 global financial crisis (i.e., March 2008 to February 2009) was excluded from the sample period, and the *log t* and club convergence tests were re-estimated for the entire sample period. The results are presented in Table A1, and the corresponding club averages are presented in Figures A1 and A2.

**Table A1: The $\log t$ Convergence and Club Convergence Test Results, Pontines (2013) and Nominal Deviation Indicators January 2004–June 2013, Excluding the Crisis Period, March 2008–February 2009**

| $\log t$ Convergence Tests | | | |
|---|---|---|---|
| Pontines (2013) | | | RIETI/Hitotsubashi |
| $\hat{b}: -2.183$ | | | $\hat{b}: -2.414$ |
| $t-stat: -83.913^a$ | | | $t-stat: -31.140^a$ |
| Club Convergence Tests | | | |
| Pontines (2013) | | RIETI/Hitotsubashi | |
| Club 1 | Brunei dollar | Brunei dollar | Club 1 |
| $\hat{b}: -0.012$ | Yen | Yuan | $\hat{b}: 0.254$ |
| $t-stat: -0.326$ | Kip | Yen | $t-stat: 4.883$ |
| | Singapore dollar | Kip | |
| | Baht | Singapore dollar | |
| | | Baht | |
| Club 2 | Rupiah | Rupiah | Club 2 |
| $\hat{b}: 0.072$ | Won | Won | $\hat{b}: 0.030$ |
| $t-stat: 1.549$ | Ringgit | Ringgit | $t-stat: 1.353$ |
| | Peso | Peso | |
| Club 3 | Riel | Riel | Club 3 |
| $\hat{b}: 0.355$ | Hong Kong dollar | Hong Kong dollar | $\hat{b}: -0.330$ |
| $t-stat: 0.968$ | | | $t-stat: -0.998$ |
| Divergent | Yuan | | |
| $\hat{b}: -3.200$ | Dong | | |
| $t-stat: -18.245^*$ | | Dong | Divergent |

[a] Indicates rejection of the null hypothesis of convergence at the 5% significance level. There are no statistics for the dong during the post-crisis period as Viet Nam is a single divergent country.

Source: Authors' calculations.

Again, the $\log t$ convergence tests reject the null of full-panel convergence. Interestingly, the club convergence test results between the Pontines (2013) and RIETI and Hitotsubashi University indicators are very similar. In both cases, there are three clubs. All clubs show $\hat{b} < 2$; thus, there is convergence in rates rather than convergence in levels. Members in club 1 are almost identical, while members in clubs 2 and 3 are identical. Moreover, the dong is divergent in both indicators.

The only noticeable difference between the two sets of results is that the yuan is a member of club 1 using the Pontines (2013) indicator but it is divergent using the RIETI and Hitotsubashi University indicator. Using the Pontines (2013) indicator as shown in Table 1, pre-crisis, the yuan belongs to club 1 where currencies appreciate in most of the subsample period but depreciate toward the end (Figure 3); post-crisis, the yuan switches to club 2 where currencies depreciate in most of the subsample period but appreciate toward the end. Belonging to such two clubs where currencies have

opposite trajectories may explain why the yuan is divergent when the whole sample period is examined.

On the other hand, comparing Table A1 with the subsample results (i.e., Tables 1 and 2), the similarity between results, based on the two alternative indicators, is profound when examining the whole sample period. Despite differences between these two sets of indicators in the two subsample periods, it is expected that the overall patterns of the relative currency values in the whole sample period would be similar, especially when the crisis period is excluded. For example, although the yen belongs to different clubs when one looks at pre- and post-crisis periods within each indicator (i.e., Tables 1 and 2), it joins the overall appreciating club 1 in both indicators when the whole sample period is investigated, which then recognizes the general appreciation pattern of its relative values for this particular club (i.e., Figures A1 and A2).

Table A1 delivers an overview of convergence in the whole sample period. However, it may overlook the dynamics within each subperiod, especially when external shocks occur such as the global financial crisis. In particular, the same country or area may belong to different clubs or be divergent when the subperiod is investigated, while such dynamic information cannot be revealed when the collapse of Lehman Brothers is excluded. Hence, the authors place more weight on the results reported in the main text.

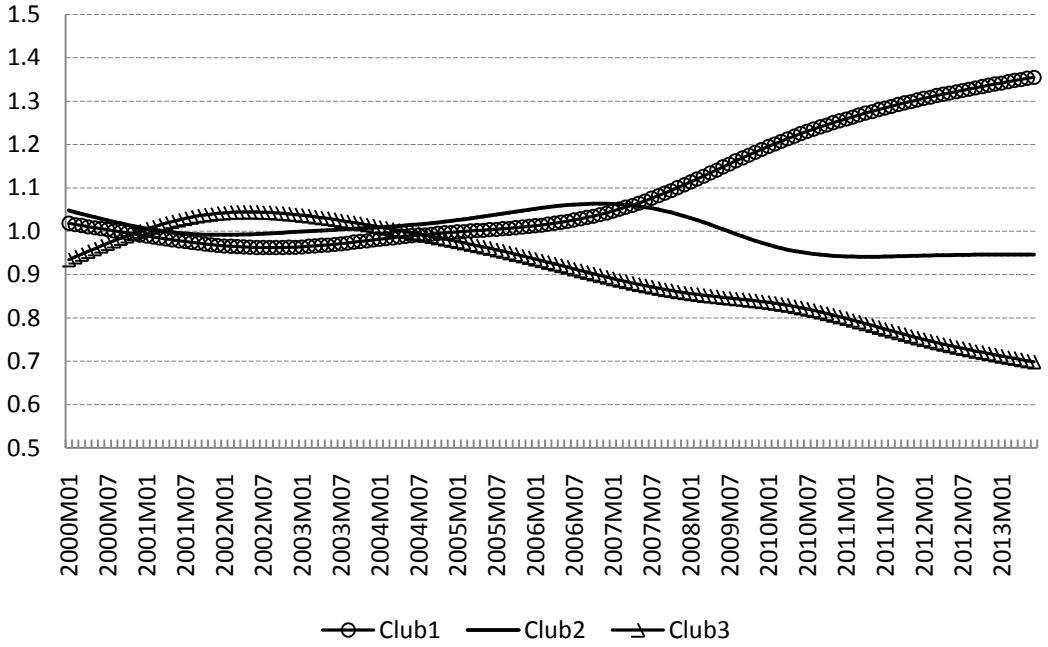
**Table A1: The $\log t$ Convergence and Club Convergence Test Results, Pontines (2013) and Nominal Deviation Indicators January 2004–June 2013, Excluding the Crisis Period, March 2008–February 2009**

| $\log t$ Convergence Tests | | | |
|---|---|---|---|
| Pontines (2013) | | | RIETI/Hitotsubashi |
| $\hat{b}: -2.183$ | | | $\hat{b}: -2.414$ |
| $t-stat: -83.913^a$ | | | $t-stat: -31.140^a$ |
| **Club Convergence Tests** | | | |
| Pontines (2013) | | RIETI/Hitotsubashi | |
| Club 1 | Brunei dollar | Brunei dollar | Club 1 |
| $\hat{b}: -0.012$ | Yen | Yuan | $\hat{b}: 0.254$ |
| $t-stat: -0.326$ | Kip | Yen | $t-stat: 4.883$ |
| | Singapore dollar | Kip | |
| | Baht | Singapore dollar | |
| | | Baht | |
| Club 2 | Rupiah | Rupiah | Club 2 |
| $\hat{b}: 0.072$ | Won | Won | $\hat{b}: 0.030$ |
| $t-stat: 1.549$ | Ringgit | Ringgit | $t-stat: 1.353$ |
| | Peso | Peso | |
| Club 3 | Riel | Riel | Club 3 |
| $\hat{b}: 0.355$ | Hong Kong dollar | Hong Kong dollar | $\hat{b}: -0.330$ |
| $t-stat: 0.968$ | | | $t-stat: -0.998$ |
| Divergent | Yuan | | |
| $\hat{b}: -3.200$ | Dong | | |
| $t-stat: -18.245^*$ | | Dong | Divergent |

[a] Indicates rejection of the null hypothesis of convergence at the 5% significance level. There are no statistics for the dong during the post-crisis period as Viet Nam is a single divergent country.

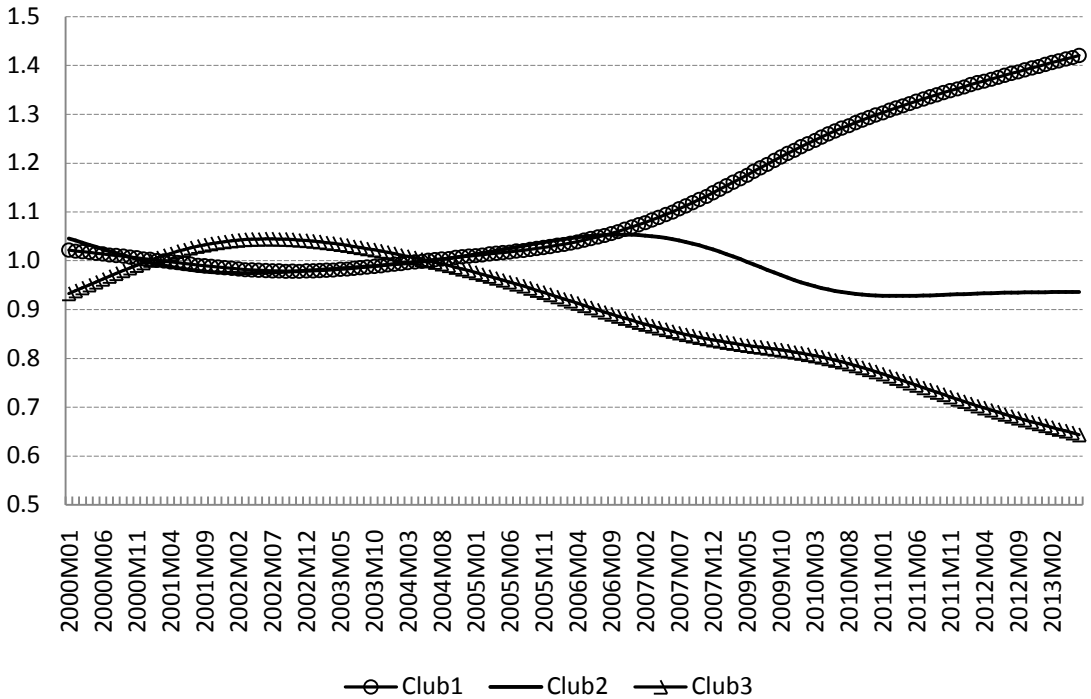
Source: Authors' calculations.

**Figure A1: Relative Transition Paths across Clubs Based on the Pontines (2013) Nominal Deviation Indicator, January 2004–June 2013, Excluding the Crisis, March 2008–February 2009**




Source: Authors' calculations.

**Figure A2: Relative Transition Paths across Clubs Based on the RIETI and Hitotsubashi University Nominal Deviation Indicator, January 2004–June 2013, Excluding the Crisis, March 2008–February 2009**




Source: Authors' calculations.