A Study on Deterministic Convergence and Asymmetric Adjustment from the Perspective of Structural Change: An Empirical Test Based on the East Asian Economic Community

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Abstract: The Association of Southeast Asian Nations - China, Japan, and South Korea - is committed to the establishment of the East Asian Economic Community in 2020. In this context, this paper examines the output convergence of the 12 countries of the East Asian Economic Community relative to China by means of smooth structural changes and the non-linear adjustment of a unit root test, and then estimates the asymmetric convergence rate. The empirical results show that, on one hand, the relative output sequence has non-linear characteristics, and only one major event affects the mean of their output differences. On the other hand, the study shows that the economic growth of ten countries experiences deterministic convergence, and the convergence rate is asymmetric. The external factors produce a strong stickiness to the relative output of most countries.

Keywords: Relative output, economic convergence, asymmetric adjustment

Economic convergence is often used to describe trends in economic disparities by studying the sustainability and transformability of economic output differences between different countries or regions. The neoclassical theory of economic growth holds that economic output of different countries or regions will converge to the same level in the long run, that is, the convergence of economic growth. However, the theory of new growth questions neoclassical theory, and believes that there is technical externality that could lead to increased capital marginal revenue, which suggests the existence of the divergence of economic growth. Since the inception of the convergence theory of economic growth, scholars from all over the world have displayed high levels of enthusiasm for further empirical research. Through testing economic convergence between different countries or regions, scholars can obtain real judgement of the economic gap

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and can propose more constructive countermeasures.

Globalization and regionalization have become the major trends of world economic development, and East Asia is seeking its cross-national cooperation and development with such a background. East Asian countries are quite different in politics, economy, and culture, and the regional historical issues and territorial disputes exacerbate the mistrust between these countries. Besides, the interference of external countries into regional cooperation also makes East Asian Economic integration more difficult, which seriously slows down its progress. However, due to the geographical location of the East Asian countries, a strong complementarity exists for these countries regarding the level of economic development and economic structure. On the whole, integration has become an inevitable trend. President of China Xi Jinpin emphasized in his speech at the opening of annual meeting of the Boao Forum for Asia in 2015 that China and the Association of Southeast Asian Nations (ASEAN) countries will work together to build a closer China-ASEAN development community, and ASEAN and China, Japan, and South Korea are committed to building the East Asian Economic Community in 2020. This paper will focus on the East Asian Economic Community, study deterministic convergence from the perspective of structural change, and examine the relative economic development of each country, in hopes of providing theoretical support for the establishment of the East Asian Economic Community.

Literature Review

Many scholars have done a lot of work in the field of empirical testing. They have tried to verify the theory of economic convergence from different perspectives, but their conclusions have not been consistent. On one hand, early studies mostly focused on the use of traditional cross-sectional regression tests, and the results were largely consistent, mostly supporting the hypothesis of convergence (Baumol, 1986; Barro, 1991; Barro & Sala-i-Martin, 1991; Mankiw et al., 1990; etc.). However, there are many defects in this regression method. For instance, a study of Evans and Karras (1996) showed that the conclusion of a cross-sectional regression is only valid if all outputs have the same first-order autoregressive dynamic characteristics and all factors that lead to persistent differences in outputs are fully controlled for. In contrast, Bernard and Dulauf (1995) pointed out that the approach of verifying convergence by using a cross-section method to determine whether the correlation coefficient is negative is not in accordance with the definition of convergence. Thus, with the rise and application of quantitative technology, scholars began to

apply a modern time series method to test the theory. Carlino and Mills (2004) proposed the concept of random convergence; that is, relative per capita output in the long term tends to close to their respective non-time-varying compensatory differential equilibrium. Carlino and Mills further argued that random convergence is consistent with the conditional convergence proposed by Mankiw et al. (1990), when relative per capita output converges to the constant compensatory differential level. Oxley and Greasley (1995) advocated the use of the time series method in the test, and refined the convergence concept according to different circumstances in the test. They conducted a case study by comparing the economic growth of Australia, the UK, and the USA, and concluded that, when applying the time series method to the test, the rejection of convergence does not mean the divergence of growth because the country may still be in a transitional stage of convergence. Therefore, they divided economic convergence into long-run convergence and catching-up convergence. Subsequent studies have dropped the hypothesis of linear structural stability, such as the application of the structural mutation of the unit root method. More research results, which were mainly based on the unit root test, were published (Quah, 1993; Carlino & Mill, 1993; Bernard & Durlauf, 1995; Dimitris, 2006; Becker et al., 2006; etc.). Still, whether the theory of convergence is supported remains unclear.

It is also worth noting that, compared with research on economic convergence between developed countries, data on convergence in East Asia is relatively limited, and a unanimous conclusion has yet to be reached. Lim and McAleer (2004) pointed out that there was insufficient evidence of economic convergence in the five ASEAN countries after four tests, including the unit root test and the co-integration test. Lee et al. (2005) used the structural change unit root test to find that, of the five ASEAN countries, economic convergence only exists in Japan and Singapore. Ismail (2008) used a panel model to find evidence of economic convergence amongst the five ASEAN countries. As for the research results of Chinese scholars, Liu et al. (2009) conducted a grouping test on the economic convergence of eight countries in Asia and found that the economic growth path between China and underdeveloped countries is gradually widening and converging to the level of developed economies. Guo (2013) believes that there is β convergence and σ convergence in the "10+3" countries of East Asia.

In this paper, by taking reference from Christopoulos and Ledesma's (2011) study on the asymmetric and non-linearity of economic growth equilibrium path regression, the author chooses

smooth structure change unit root test method, proposed by Becker et al. (2006), to study the economic convergence of member countries of the East Asian Economic Community.

The Definition of Deterministic Convergence

Judging whether economic convergence exists between countries or regions can be achieved by examining the time series of the per capita output disparities. Bernard and Durlauf (1995, 1996) presented a definition of deterministic convergence as follows:

Formula 1

$$\lim_{k\to\infty} E(y_{i,t+k} - y_{j,t+k} \mid I_t) = 0$$

Here y represents per capita output, and i and j respectively represent different countries. It can be seen that economic convergence requires that the time series of the per capita output gap is stable and zero-mean.

And the unchangeable-over-time Wold decomposition form is:

Formula 2

$$y_{i,t} - y_{j,t} = \kappa_{i,j} + \sum_{r=0}^{\infty} \lambda_{i,j,r} \varepsilon_{i,j,t-r}$$

If the relative income is compatible with Formula 2, Formula 1 will be valid. In other words, convergence is determined. Here $\varepsilon_{i,j,t-r}$ is the error term and $\kappa_{i,j} = 0$. $\lambda_{i,j,r}$ is square plus (Bernard & Durlauf, 1996).

After an analysis of the above definition, it seems that relative output which satisfies the zero-mean and remains stable are too strict as convergence requirements (Pesaran, 2007). In view of this, a new concept of deterministic convergence emerges, which only requires the time series of the relative economic output to be stable. Specifically, *I* can be expressed as follows.

Formula 3

$$\lim_{k\to\infty} E(y_{i,t+k} - y_{j,t+k} \mid I_t) = \alpha_{ij}$$

Here, α_{ij} is a constant parameter which may be constrained by a break point. In this case, $\kappa_{i,j}$ in Formula 2 may be non-zero, and the difference in average growth rates of the two countries' economic outputs is stable and zero-mean.

Research Methods

In this paper, the basic idea of the model is to carry out Fourier series expansion of the deterministic trend of economic growth, use a trigonometric function to describe the non-linear characteristics of the deterministic part of the variables, and analyze the variables through a smooth transfer function which is used to describe the asymmetric adjustment of deterministic trend. Specifically,

First, use the following model to describe a random variable y_t.

Formula 4

$$y_t = \delta(t) + v_t$$

Here $v_t \sim N(0,\sigma^2)$. And $\delta(t)$ is a deterministic mean, changeable over time. According to studies by Becker et al. (2006), the Fourier series expansion is now used to approximate the unknown $\delta(t)$.

Formula 5

$$\delta(t) = \delta_0 + \sum_{k=1}^{G} \delta_1^k \sin(\frac{2\pi kt}{T}) + \sum_{k=1}^{G} \delta_2^k \cos(\frac{2\pi kt}{T})$$

Here, k is the frequency of the Fourier function, t is the time trend, T is the sample size, and $\pi = 3.1416$. If there is at least one frequency *k* in $k = G_1, \Lambda, G_M$ ($G_1 > 0$) that is rejected by the original hypothesis $\delta_k = 0$, the non-linear part of Formula 5 can fully explain the deterministic

part of y_t and there is at least one structural change in the data generation process. And under the setting of this model, the breakpoints are described as a smoothing process rather than horizontal changes, but both have the same economic meaning.

Given that Ludlow and Enders (2000) argued that a single frequency in empirical application is sufficient to approximate the Fourier expansion, Formula 5 can be simplified as:

Formula 6

$$\delta(t) = \delta_0 + \delta_1 \sin(\frac{2\pi kt}{T}) + \delta_2 \cos(\frac{2\pi kt}{T})$$

Based on the ideas of Becker et al. (2006), this paper uses Formulas 4 and 6 to choose the optimal value of k by using the Bayesian Information Criterion (BIC) within the frequency range $[0.1, 0.2, \mathrm{L}\ , 4.9, 5]$. Set the original hypothesis $H_0 : \delta_1 = \delta_2 = 0$ to test the alternative hypothesis $H_1 : \delta_1,\ \delta_2$ are not equal to 0 at the same time. And then compare with the Monte Carlo simulation results listed by Becker et al. (2006), that is, the empirical distribution table approximates this test, and observe the F -statistic.

In addition, we can get another layer of information from the Fourier transformation. If the selected frequency is an integer, then this function may make a smooth transition temporary. Otherwise, if the frequency is in fractional form, it means there is a lasting change because at this time this function cannot finish a complete cycle of oscillation. In this case, the model should be:

Formula 7

$$y_t = \delta_0 + \delta_1 \sin(\frac{2\pi kt}{T}) + \delta_2 \cos(\frac{2\pi kt}{T}) + v_t$$

The original hypothesis of the unit root can be expressed as:

$$H_0 : v_t = \mu_t, \mu_t = \mu_{t-1} + h_t$$

Here, h_t is the zero-mean stationary process. The statistic test is conducted through the following three steps:

The first step involves finding the optimal frequency k^* and using the least squares method to estimate the non-linear deterministic part of Formula 7. Then the ordinary least squares (OLS) residual is calculated.

$$\hat{v}_t = y_t - [\hat{\delta}_0 + \hat{\delta}_1 \sin(\frac{2\pi k^* t}{T}) + \hat{\delta}_2 \cos(\frac{2\pi k^* t}{T})$$

In the second step, the unit root test is performed on the OLS residuals obtained in the first step. Firstly, by trying the linear unit root test.

Formula 8

$$\Delta v_t = \alpha_1 v_{t-1} + \sum_{j=1}^{p} \beta_j \Delta v_{t-j} + u_t \qquad \text{Formula 8}$$

Since the mean regression may exhibit asymmetric characteristics, the following non-linear model is used for the unit root test.

Formula 9

$$\Delta v_t = \rho v_{t-1}(1 + \exp(\theta v_{t-i}))^{-1} + \sum_{j=1}^{p} \beta_j \Delta v_{t-j} + u_t \quad i = 1,2,\Lambda\ ,L$$

Here, the recognition limit is $\theta > 0$ and u_t is a white noise error term.

Formula 8 is the standard Augmented Dickey-Fuller (ADF) and the convergence rate is assumed to be symmetrical. Firstly, the Fourier function is used to describe the time sequence structure and then perform the standard linear ADF test. It is called the Fourier-ADF test, namely the FADF test. Referring to the FADF threshold table given by Christopoulos and Leon-Ledesma

(2009), the original hypothesis of the unit root can be rejected if the t value of coefficient α_1 in the test exceeds the FADF threshold.

Formula 9 is the stability test proposed by Park and Shintani (2009), which means that the adjustment rate of the variable of the equilibrium level deviation is asymmetric and depends on the distance from the equilibrium deviation position. It follows a logistic smoothing transition autoregressive process (LSTAR). The logistic function considers different effects of positive and negative deviations from equilibrium, which implies that the velocity of mean regression depends on the relationship between the transition variable and a stable state. This setting conforms to the theoretical form of convergence rate outside a steady state. The convergence rate near the steady state ($v_{t-i} = 0$) is equal to 0.5ρ. When $v_{t-i} < 0$ ($v_{t-i} > 0$), it rises (falls). Here, v_{t-i} is the value after removing the mean from the relative output, which means the deviation of relative output to the equilibrium position.

To test the existence of a unit root of the original hypothesis, Park and Shintani (2009) proposed the following *t*-statistic minimum formula.

Formula 10

$$\inf - t = \inf_{\theta \in \Theta} T(\theta)$$

Here, the function $T(\theta) = \dfrac{\hat{\rho}(\theta)}{s.e.(\hat{\rho}(\theta))}$ is to test the t value of the original hypothesis $H_0 : \rho = 0$, and $\Theta = [\underline{\theta}, \overline{\theta}]$ and $0 < \underline{\theta} < \theta < \overline{\theta}$. The value of θ can be estimated in the parameter space $[\frac{1}{10}Q, 10^3 Q]$ through $\hat{\theta} = \arg\min_{\theta \in \Theta} T(\theta)$, here $Q = (\dfrac{1}{\sqrt{\sum_{t=1} v_t^2 / T}})$. Therefore, $\inf - t$ is the minimum value of the t-statistic (negative) calculated by the unit root test within the range of the value of the transition speed parameter. If the original hypothesis of the unit root in the second step of the test is rejected, then proceed to the third step, that is, set the original hypothesis $H_0 : \delta_1 = \delta_2 = 0$ to test that the alternative hypothesis H1: δ_1, δ_2 is not zero at the same

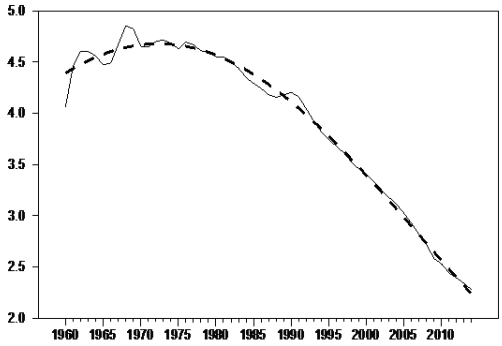
time. If the original hypothesis is rejected in the test, the variable is considered non-linearly stable.

The Data Sources and Empirical Results

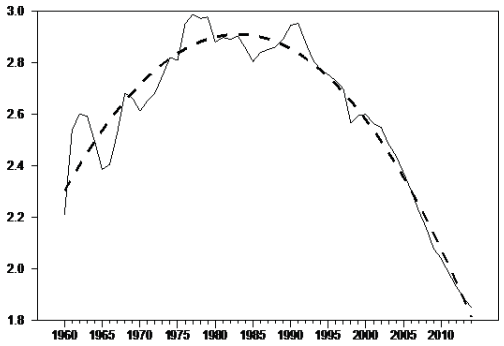
The subject of this study is the East Asian Economic Community, which is composed of 13 countries. In terms of relative output per capita, this paper examines the deterministic asymmetric economic convergence between China and the other member countries of the East Asian Economic Community, that is, Japan, South Korea, and the ten countries of ASEAN, namely Malaysia, Indonesia, Thailand, the Philippines, Singapore, Brunei, Vietnam, Laos, Myanmar, and Cambodia. However, due to data availability and other issues, the time span of the data selected in this paper is roughly the same, but is slightly different (see Column 8 in Table 1). The data in the empirical analysis is based on the logarithmic form of the relative output per capita of the 12 countries of the East Asian Economic Community to China, which is derived from the constant US dollar GDP per capita in 2005. The data on Myanmar are from the United Nations Statistics Division and the other data from the World Bank Online Database.

The figure below (Figure 1) shows the actual value (solid line) of the GDP per capita level of each country to China and the fitted value (dashed line) calculated using the Fourier function. It can be seen from Figure 1 that the Fourier function can be fitted to the relative per capita output sequence with a smooth structure change. Apparently, these countries show a very different form of relative per capita GDP. From the general trend point of view, the relative per capita output of some countries to China shows a slight increase and then continues to decline. And the general tuning point appears in the 1970s or 1980s, such as with Japan, South Korea, Malaysia, Indonesia, Thailand, Singapore, and Myanmar. Particularly, the relevant data of Indonesia, Thailand, the Philippines, and Myanmar gradually changes from positive to negative, which indicates that China has caught up and even exceeded the four countries in terms of economic development. In contrast, for Japan, South Korea, Malaysia, and Singapore, the relative per capita output to China has been greater than 0, which means their per capita GDP has been higher than China's. But considering the trend of economic development, the gap between China and the four countries is continually reduced, especially so for the gap between China and Malaysia. In addition, for Brunei, Vietnam, Laos, and Cambodia, the GDP per capita relative to China has the trend of significantly and monotonically declining. Particularly, the GDP per capita of Brunei relative to China has been higher than China, but the gap is becoming smaller and smaller. For Vietnam, Laos, and Cambodia,

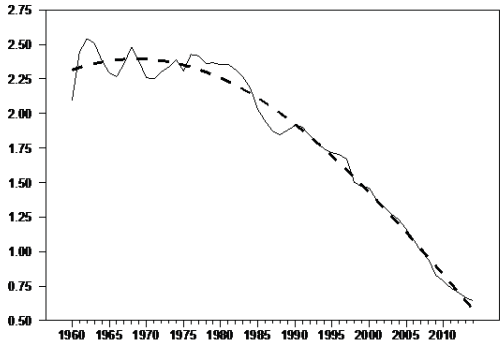
the relative GDP per capita to China has been lower than China, and the gap between China and the three countries is growing. The time span of the relevant data for the four countries is shorter. During the same shorter time span, comparison with the other countries showed a monotonically decreasing trend for all countries, confirming the rapid economic development of China and its great economic achievements. In addition, from the shapes of the curves in the figure, we can find their common characteristic, which is the possibility of smooth structural changes mostly occurring in the 1970s and 1980s, when China had reformed its economic system and policy, applied the reform and opening up policy, and started economic exchanges with East Asian countries. To sum up, the relative output does not show a clear and consistent steady state, and instead is subject to the significant impacts of structural changes. Therefore, when we conduct the convergence test, we must consider that these factors improve the stability of the test and ensure the reliability of the conclusions.



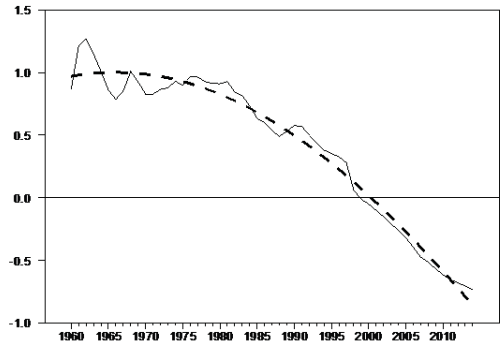
Japan



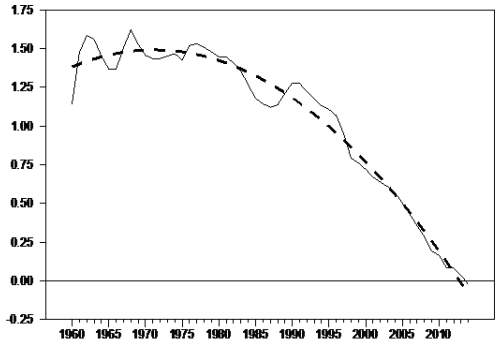
South Korea



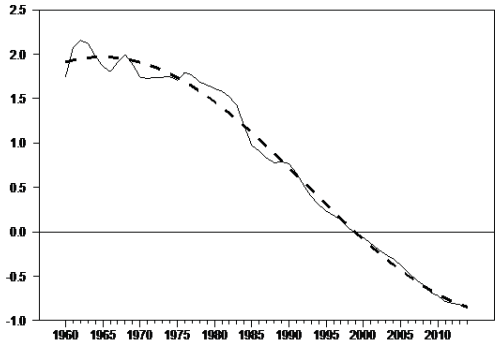
Malaysia



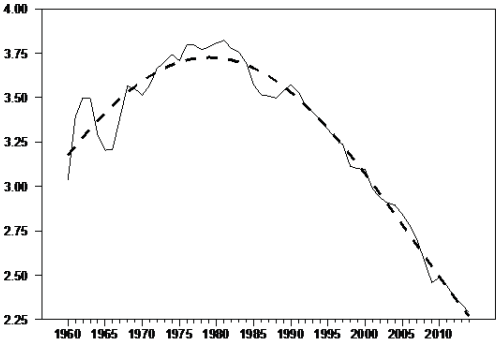
Indonesia



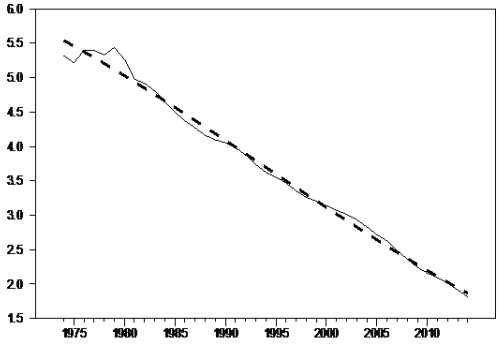
Thailand



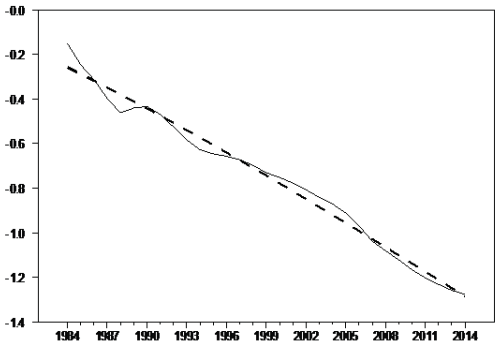
The Philippines



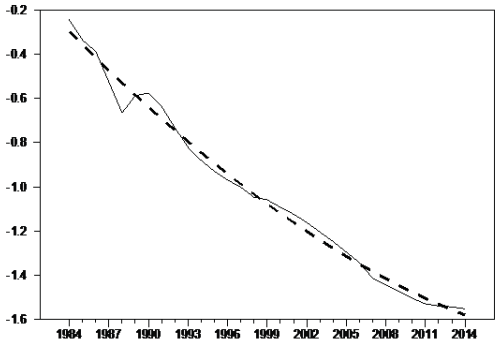
Singapore



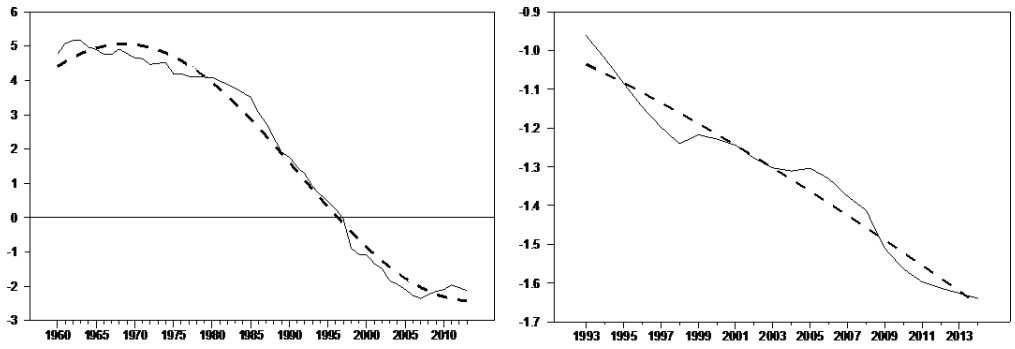
Brunei



Vietnam



Laos



Myanmar Cambodia

Figure 1. The actual value (solid line) and the fitted value (dashed line) of the relative GDP per capita of member countries of East Asian Economic Community.

In the case of fitting the relative output sequence through the Fourier function, this paper takes the maximum value of k as 4 by referencing the study of Christopoulos and Ledesma (2011), and searches step by step for the optimal frequency, starting from 0.1. The results of the optimal value of k are shown in Column 1 in Table 1. Results show that the optimal frequency of the relative per capita GDP sequence of the 12 countries of the East Asian Economic Community is less than 1, which means that the structural change for all sequences is only one, and the smaller the value of k is, the longer the break point lasts, indicating that the effect of this event on the region's economy is more lasting and, vice versa, the larger the value of k is, the shorter the effect is. In addition, by examining the joint distribution of sine and cosine, that is, the value of $F_\mu(\hat{k})$ in Column 2 in Table 1, this indicates that the Fourier function can well characterize the relative GDP per capita sequences in these regions, implying that these sequences conform more to the non-linear mean regression process than the linear one.

Country	(1) $\hat{k}$	(2) $F_\mu(\hat{k})$	(3) FADF	(4) θ	(5) ρ	(6) Convergence rate	(7) $\inf - t$	(8) Time span
Japan	0.4	2653.3346	-6.8762***	2.6833	-1.2252	61.25%	-7.0315***	1960-2014
South	0.1	414.5910	-3.6563*	1.7234	-0.9681	48.40%	-5.5803***	1960-2014

Korea								
Malaysia	0.3	1203.3065	-4.8544***	4.1578	-0.9149	45.74%	-5.0296***	1960-2014
Indonesia	0.2	909.3853	-5.0971***	2.1590	-0.7245	36.22%	-4.9918***	1960-2014
Thailand	0.1	869.2023	-5.3556***	3.2287	-0.8100	40.50%	-5.5713***	1960-2014
Philippines	0.5	2719.2677	-5.09439***	2.2552	-0.7288	36.44%	-5.1303***	1960-2014
Singapore	0.5	684.7314	-6.3417***	4.2326	-1.3036	65.18%	-7.2769***	1960-2014
Brunei	0.2	2298.1053	-4.6747***	3.8362	-0.8608	43.04%	-4.1237**	1974-2014
Vietnam	0.1	924.8595	-2.9429	8.6608	-0.6475	32.37%	-4.2295**	1984-2014
Laos	0.1	1333.3112	-4.4054**	5.4250	-1.3681	68.40%	-5.1845***	1984-2014
Myanmar	0.6	1838.0944	-1.7836	0.6904	-0.3125	15.62%	-2.5256	1960-2013
Cambodia	0.1	201.5718	-3.0971	5.3084	-0.6997	34.99%	-3.1316	1993-2014

Table 1. The unit root test of relative output based on Fourier function.

Note: (***), (**), and (*) means that the original hypothesis of the unit root is rejected at the significance level of 1%, 5%, and 10% respectively. The underscore represents that the original linear hypothesis is rejected at the traditional significance level. The $F_\mu(\hat{k})$ test is distributed as a F-statistic under the null hypothesis with 2 degrees of freedom. The critical value is listed in the Table 1 of Becker et al. (2006). The optimal lag is selected through SBIC (the Schwarz Bayesian Information Criterion).

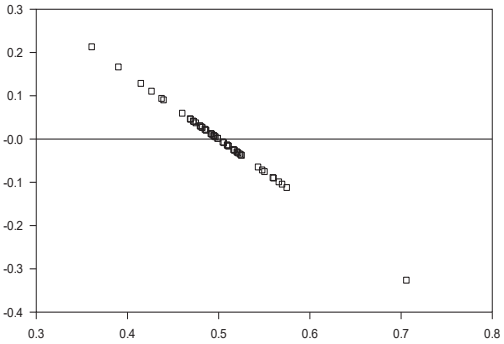
The smoothness of the residuals obtained from the Fourier function is then checked. The FADA statistic (see Table 1, Column 3) shows that seven countries (Japan, Malaysia, Indonesia, Thailand, the Philippines, Singapore, and Brunei) rejected the original hypothesis at the significance level of 1%; one country (Laos) rejected the original hypothesis at the significance level of 5%; and one country (South Korea) rejected the original hypothesis at the significance level of 10%. The results show that, if regarding the economic convergence process as a symmetric convergence process, only taking structural change with an unknown form and time point into consideration, convergence exists for the nine countries of the East Asian Economic Community.

If taking the structural change with unknown forms and time points, as well as the convergence rate into the analysis framework, the LSTAR unit root test of Formula 9 is used. The test is to calculate the minimum *t*-statistic of Formula 10 for the transfer variable $v_{t-i}, i = 1,2,3,4$. And finally, a test result that minimizes the sum of squares of residuals (SSR) is selected.

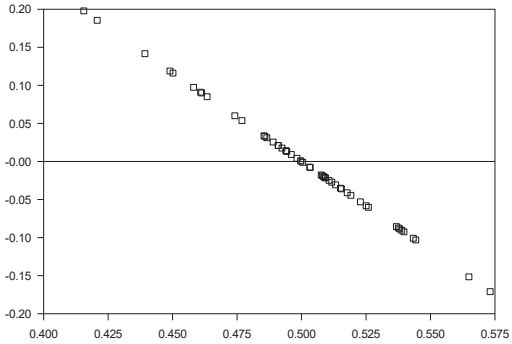
Column 7 in Table 1 lists the test results. It can be seen that, amongst the 12 countries, , only two countries (Myanmar and Cambodia) cannot reject the original hypothesis of the unit root in terms of relative per capita GDP, both countries showing a trend of relative economic divergence. Eight countries (Japan, South Korea, Malaysia, Indonesia, Thailand, the Philippines, Singapore, and Laos) reject the original hypothesis of the unit root at the significance level of 1%, and the other two countries (Brunei and Vietnam) reject the original hypothesis at the significance level of 5%. The results show that the above-mentioned ten countries of the East Asian Economic Community achieve relatively stable economic performance and convergence, if one takes two aspects into consideration at the same time, that is, the sequence's structural changes with unknown forms and time points, and the asymmetry of the convergence rate. Column 5 in Table 1 lists the estimated value of parameter ρ in detail. Therefore, we can derive the average convergence rate, namely $\rho/2$ (see Column 6 in Table 1.) when the relative GDP per capita is close to the mean (that is, close to the steady state, v_{t-i} is nearly zero). Of the estimated value of ρ, from the -1.3681 of Laos to the -0.3125 of Myanmar, the average is -0.8803, indicating that the overall average convergence rate is 44.02% as the relative GDP per capita of each country is close to the steady state, and Laos is the fastest, while Myanmar is the slowest. The parameter θ reflects the transition speed of the LSTAR process and accurately characterizes the speed of the transfer variable between the two states. As can be seen from the estimated values in Column 4 of Table 1, most estimated values of θ are not large, indicating that the external shocks show a strong stickiness to the relative output effects of most countries; that is, the transition rate between two states is relatively slow. And relatively speaking, the estimated value of θ for Vietnam is greater, which means a faster rate of transition.

In addition, we can get the conversion function ($-\rho(1+\exp(\theta\varepsilon_{t-d}))^{-1}$) of each country during each time period through the estimated values of ρ and θ, namely the instantaneous convergence rate. If one draws the trend of the convergence rate of the relative GDP per capita of the member countries of the East Asian Economic Community, one will get the relevant scatter plot (see Figure 2). This shows the scatter plot of the convergence rate ($-\lambda(1+\exp(\theta\varepsilon_{t-d}))^{-1}$) relative to the equilibrium deviation value (ε_{t-d}), where the convergence rate exhibits an apparent

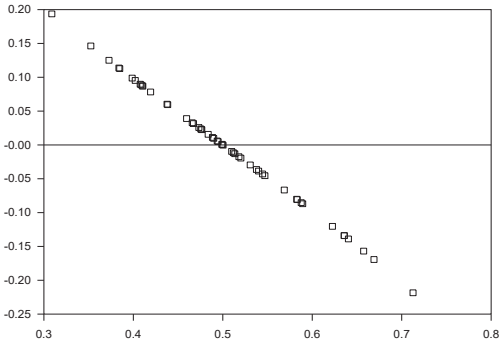
asymmetric characteristic, and the convergence rate at the steady state ($\varepsilon_{t-d} < 0$) is faster than that at the steady state above ($\varepsilon_{t-d} > 0$).



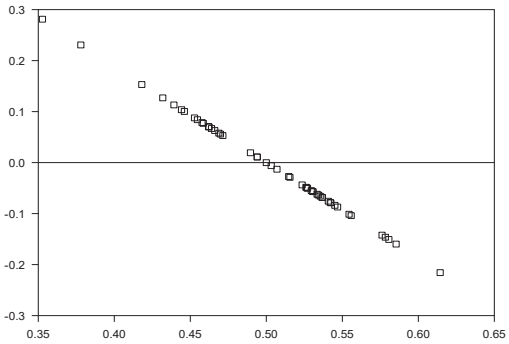
Japan



South Korea



Malaysia



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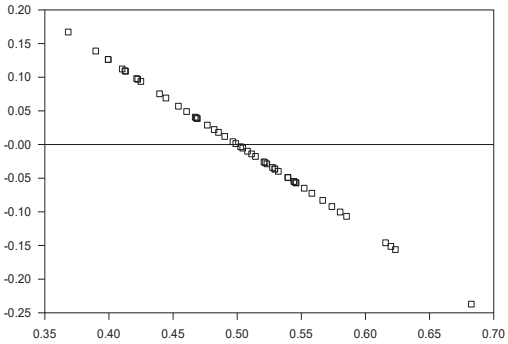

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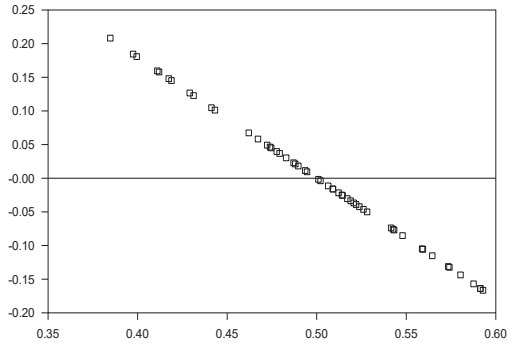

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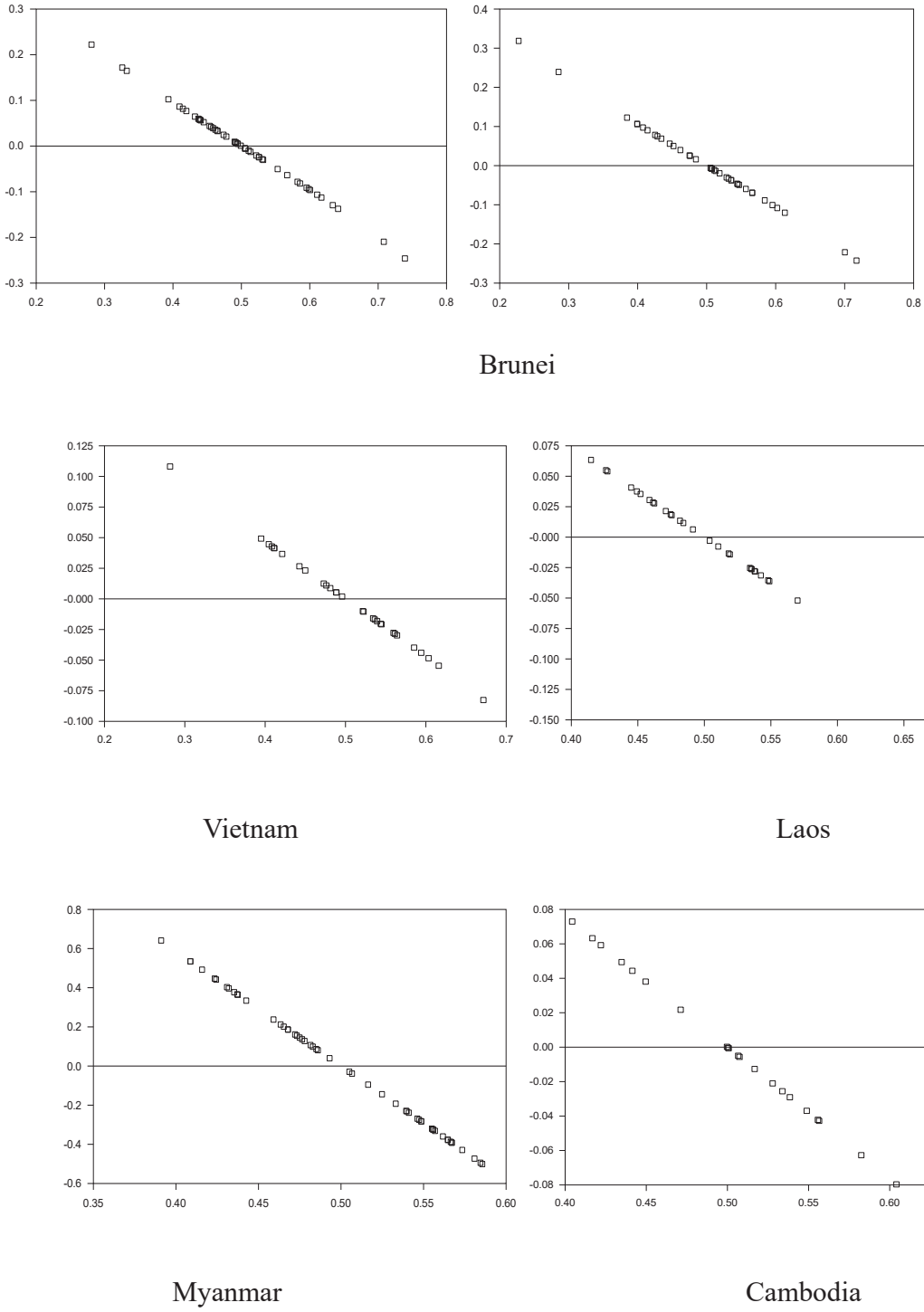

Figure 2. The relative GDP per capita of the East Asian Economic Community: convergence rate (horizontal axis) versus equilibrium deviation (vertical axis).

Conclusion and Analysis

Based on the research of Christopoulos and Ledesma (2011) and the quantitative method proposed by Becker et al. (2006), and Park and Shintani (2009), this paper uses a non-linear model to test the economic convergence of the member countries of the East Asian Economic Community. These tests can be regarded as an improved method based on the studies of Perron (1990), Zivot-Andrews (1992), and Bai and Perron (1998), which further takes the asymmetric characteristics of the adjusted rate into consideration. It has the advantage of being able to determine whether the effects of external factors on economic variables are persistent or temporary. Results show that the 12 countries of the East Asian Economic Community have non-linear time characteristics compared with China's per capita GDP, and nine of them show a deterministic convergence of their symmetric convergence rates. The economic growth of ten countries is the deterministic convergence of the asymmetric convergence rate, and most of them exhibit stickiness to economic shocks. This paper argues that, within the range of the sample, the impact of some major events will result in an asymmetric adjustment of the mean regression rate, which it is impossible to characterize by the linear model. Besides, this paper also proves that the structural breakpoints and asymmetric adjustment rates are extremely important in analyzing the relative output convergence. These breakpoints can explain most of the cases that reject the original hypothesis of the unit root. And the asymmetric adjustment caused by significant shocks is also indispensable for the analysis of the convergence state of countries (those which reject the original hypothesis).

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