

A Nonlinear Empirical Test on the Stochastic Convergence of Economic Growth: A Case Study of East Asian Economic Community

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Abstract

In this paper we use the nonlinear unit root test and the replacement residual sampling, i.e. the Bootstrap method, to analyze the relative dynamic growth of GDP per capita between China and EAEC countries, observe the stochastic convergence of economy, and further divide the convergence into the long-term convergence and process convergence. The empirical results show that: compared with China, all EAEC countries' per capital output gap is characterized by the nonlinear time series and the majority of countries' in the nonlinear convergence. This gives a new perspective for the market-guided economic integration planning development, as well as reducing regional disparities.

Keywords: stochastic convergence, nonlinear, East Asian Economic Community (EAEC)

1. Introduction

Economic growth theory plays an important role in exploring on the stochastic behaviors of different countries' (or regions') economic gap. For the neoclassical theory of economic growth, as an important basis of economic theory, one of assumptions is the law of diminishing marginal returns of capital, which means different countries' capital-labor ratio changes inversely with the economic growth, i.e. the economic growth indicates a convergence process. However, this theory is challenged by the new growth theory. According to the new growth theory, technological externality can lead to increasing marginal returns of capital, and therefore the economic growth should be in a divergence process. The different expected economic growths derived from the two theories have triggered great interest of scholars and thus been investigated to a great degree.

Many scholars have done a lot of empirical work on economic convergence, but the conclusions are different. On the one hand, the traditional cross-sectional regression method could lead to the same result basically, and support the convergence assumption mostly. However, there are many flaws in this method. For example, Evans and Karras' (1996) study showed that only when all outputs had the same first-order autoregressive dynamic feature and all factors causing the persistent differences of outputs were under the control, could the cross-sectional regression draw meaningful conclusions. However, Bernard and Durlauf (1995) pointed out that using the cross-sectional method to judge whether the correlation coefficient was positive or not violated the definition of convergence concept. Therefore, on the other hand, scholars began to seek for using the modern time series to test the theory. Carlino and Mills (1993) proposed the concept of stochastic convergence, which assumed that the relative output per capita in the long run tends to be convergent toward their respective compensating differential equilibrium that does not change with time differences. Carlino and Mills further pointed out that when the relative output per capita converged to the same level of compensating difference, the stochastic convergence was in accordance with the conditional convergence proposed by Mankiw et al. (1992). Oxley and Greasley (1995) compared the economic growth in the USA and that in Australia and the UK and argued that when applying the time series to the test, the rejection to convergence did not imply the divergence of growth, because regions might still in the convergence transmission process. Therefore, they divided economic convergence into the long-run convergence and the catching-up convergence. Subsequent studies did not focus on the assumption of stability of linear structure, such as the application of structural abrupt change of unit root method. Lots of research results have shown up and the unit root test was the main research method. However, it is unclear whether these researches support the convergence conclusion (see references: Quah, 1993; Carlino & Mill, 1993; Bernard & Durlauf, 1995; Loewy & Papell, 1996; Datta, 2003; Bentzen, 2005; etc.).

Subsequently, Dimitris' (2006) studies indicated that the nonlinear model-based unit root test was more effective than the traditional DF test concerning the refusal of original unit root assumption, and further confirmed that the nonlinear mean reverting process could better describe the real GDP trend.

We should notice that, compared to the researches on western developed countries' economic convergence issue, the research on East Asian countries' seems to be rather limited and has not yet reached the same conclusion. Lim and McAleer (2004) performed unit root test, co-integration test, and two other tests and pointed out that there was no sufficient evidence supporting the existence of economic convergence among the five ASEAN (Association of Southeast Asian Nations) countries. Lee et al. (2005) applied the structure changing unit root test and found that there was economic convergence only between Singapore and Japan of the five ASEAN countries. Ismail (2008) used the panel model and found the evidence supporting the existence of economic convergence among the five ASEAN countries. Chowdhury and Mallik's (2011) nonlinear unit root test results showed that among the eight ASEAN countries and regions being tested, the economic convergence only existed between Japan and Taiwan. Peiying Guo (2013) believed that there was a β convergence and σ convergence among the "10+3" ASEAN countries and regions.

On the basis of previous research, considering the fact that macro-economic variables' nonlinear feature and nonlinear model have more advantages in dealing with the structural change, in this paper we focus on the 13 ASEAN countries and regions and try to using nonlinear unit root test to study the East Asian Economic Community's economic convergence issue by learning from Chong's (2008) nonlinear dynamic convergence test on transition economies, with a view to providing a new perspective to analyzing the convergence and divergence of economy.

2. Research Methods

Chinese President Xi Jinping, in his speech at the 2015 Boao Forum for Asia Annual Conference opening, emphasized that China will build a closely-connected China-ASEAN community with ASEAN countries and regions, and the ASEAN and China, Japan, and South Korea are committed to the establishment of the East Asian Economic Community in 2020. On the one hand, East Asian countries are quite different in politics, economy, and culture. Historical issues and territorial disputes exacerbate the distrust of all parties. Besides, the interference from certain exterior countries also causes lots of difficulties to the economic integration of East Asian countries, slowing down the integration process. On the other hand, East Asian countries are geologically connected. Their economic development level and structure are complementary. The mutual economic ties are increasingly close. On the whole, integration has become an inevitable trend. In this paper, referring to Oxley and Greasley's definition of convergence, we further divide the stochastic convergence into the long-run convergence and the process convergence, examining the economic development of East Asian countries from a point view of convergence theory. (The long-run convergence refers to a long-run stable equilibrium of two different regions at different levels of outputs. The process convergence means that two regions' economic growth is in a process of convergence. Although the convergence is incomplete, the output gap between the two regions (whether it is positive or negative) narrows down continuously with the passage of time).

In order to judge whether it is a long-run convergence or process convergence, in this paper we firstly conduct the linear test on economic growth, and thus select the appropriate stochastic regression method. In other words, we use linear or nonlinear unit root to test the existence of convergence. Specific steps are as follows.

2.1 Linear Test

By referring to the study of Chong et al. (2008), in this paper we firstly use the nonlinear test method proposed by Luukkonen et al. (1988). Specifically, we choose the augmented first-order test procedure to set up the linear test model.

$$rGDP_t = \theta_0 + \sum_{k=1}^p (\theta_{1k} rGDP_{t-k} + \theta_{2k} rGDP_{t-k} rGDP_{t-d} + \theta_{3k} rGDP_{t-k} rGDP_{t-d}^2) + \theta_4 rGDP_{t-d}^3 + \varepsilon_t \quad (1)$$

Here, $rGDP = \ln GDP_{other} - \ln GDP_{CN}$. GDP refers to the real per capita gross domestic production, θ is a parameter, and ε is the independent identically-distributed error term.

The original hypothesis $H_0: \theta_{2k} = \theta_{3k} = \theta_{4k} = 0, k \in \{1, \dots, 4\}$, i.e. $rGDP$ is linear.

The alternative hypothesis $H_1: rGDP$ is nonlinear.

The optimal lag length k and the optimal delayed lag length d are selected on the basis of experience analysis of

sample data. In this paper, $k \in \{1, \dots, 4\}$, and $d \in \{1, \dots, 4\}$, and we use the F statistic to complete the hypothesis testing. Given the small sample size characteristics of the problem, the error term ε may be far different from the asymptotically limit normal distribution. Here, we use the Bootstrap computer simulation method, proposed by Efron (1979), to examine the statistics' msv (marginal significance value).

2.2 Nonlinear Unit Root Test and Trend Term Significance Test

On the basis of STAR (Smooth Transition Autoregression) model, Kapetanios, Shin, and Shell (2003) extended the linear ADF unit root test to the nonlinear field. The original hypothesis is still that the sequence contains unit roots. The alternative hypothesis is that the sequence is nonlinear stable.

KSS nonlinear unit test model :

$$\Delta x_t = \sum_{j=1}^p \rho_j \Delta x_{t-j} + \delta x_{t-1}^3 + v_t \quad (2)$$

Here, x_t is a de-trending sequence reducing the trend and mean. We examine:

The original hypothesis: $H_0: \delta = 0$, i.e. the sequence has a unit root vs.

The alternative hypothesis: $H_1: \delta < 0$, i.e. the sequence is nonlinear stable.

Although this model is of great value to the study of nonlinear convergence, it cannot identify the significance of certainty time trend, thus cannot distinguish between long-run convergence and process convergence. Chong et al. (2008) suggested to adding additional intercept μ and trend term $G(trend)$ to the Formula (2) and getting the model.

$$\Delta rGDP_t = \mu + \sum_{j=1}^p \rho_j \Delta rGDP_{t-j} + \delta rGDP_{t-1}^3 + \phi G(trend) + \xi_t \quad (3)$$

Here, $rGDP_t$ is the original sequence, no de-trending or de-mean. $G(trend)$ is the trend in function. Linear trend (t) and nonlinear trend (t^2) are two common trend variables. ξ_t is the independent identically-distributed error term. The lag length selection method of the traditional linear model can still be applied to this nonlinear model. Existing studies show that the tail term significance-based “ $t-sig$ ” method is characterized by testing level stability and high effectiveness, superior to the traditional information criterion. Therefore, in this paper we refer to this method to select the lag length (Kun Wang et al., 2012), taking 10 as the maximum lag length, and selecting the lag length according to whether the t statistic of the lag term is significant or not. The original hypothesis is still that the sequence contains unit root ($\delta = 0$). The alternative hypothesis is that the sequence is nonlinear stable ($\delta < 0$). Similar to Formula (3), if there is no unit root ($\delta < 0$), it indicates the sequence is a nonlinear convergence. If the certainty trend term is significant ($\Phi \neq 0$), it indicates the existence of a nonlinear convergence, i.e. the process convergence. If the certainty trend term is insignificant ($\Phi = 0$), it indicates the existence of the other nonlinear convergence, i.e. the long-run convergence. If the sequence has a unit root, it indicates that it is diverging over time. Kapetanios, Shin and Shell have demonstrated that the t statistic is no longer subject to the progressive standard normal distribution in this model. Therefore, in this paper we use the Bootstrap method to select the marginal significance value (msv) in the empirical study.

3. Data Source and Empirical Results

3.1 Data Source and Indicator Selection

This paper focuses on the 13 countries of regions of East Asian Economic Community and examines the stochastic economic convergence of the relative per capital output of other countries and regions to China, with China as the benchmark. In other words, it is to examine the relative output of Japan, South Korea, and 10 ASEAN countries (Malaysia, Indonesia, Thailand, Philippines, Singapore, Brunei, Vietnam, Laos, Myanmar, and Cambodia) to China. However, due to the availability of data and other issues, the time span of data in this research varies (see Table 1). The data for empirical analysis is based on the logarithmic form of per capita output of 12 East Asian Economic Community countries to China, which is derived from the US dollars per capita GDP of every country in 2005. Myanmar data is from the United Nations Statistics Division, and others from the World Bank online databases.

3.2 Empirical Results

3.2.1 Linear Test

Linear test results (Table 1) show that in the 12 countries of the East Asia Economic Community, seven countries' linear hypothesis can be rejected at the 1% level of significance, and five countries' linear hypothesis can be rejected at the 5% level of significance, which indicates that the repectively relative real per capita output of the 12 countries to China is nonlinear. The empirical results are quite different from existing studies, which implies that the East Asian countries' relative real per capita output sequence is nonlinear. Compared to the linear fitting, the nonlinear model is more suitable for the research on East Asian countries' economic convergence.

Table 1. Linear test results

Series	k	d	F-statistic	Bootstrap <i>msv</i>	Data time span
Japan	1	2	5.5536	0.001***	1960-2014
Korea	2	4	2.1280	0.026**	1960-2014
Malaysia	2	1	1.5775	0.042**	1960-2014
Indonesia	1	2	6.2955	0.001***	1960-2014
Thailand	2	4	3.2476	0.005***	1960-2014
Philippines	1	2	5.0661	0.002***	1960-2014
Singapore	4	3	1.4792	0.026**	1960-2014
Brunei	3	4	2.2396	0.008***	1974-2014
Vietnam	3	1	2.8853	0.002***	1984-2014
Laos	1	3	2.6067	0.038**	1984-2014
Myanmar	2	2	3.4076	0.006***	1960-2013
Cambodia	1	1	1.4882	0.039**	1993-2014

Note. ***, **, * represents the significance respectively at 1%, 5%, and 10% level. The critical value comes from the replacement residual sampling Bootstrap method.

3.2.2 The Unit Root Test with Linear Trend Term and the Trend Term Significance Test

On the basis of linear model test, we use the nonlinear STAR model, with intercept term and linear trend term, to conduct the unit root test on the relative per capita output sequence, consisted of the 12 countries being rejected by the linear hypothesis. In other words, by means of comparing the t value nonlinear variable's head coefficient δ with the critical value t derived from the Bootstrap method, we can judge whether the real per capita output sequence of certain region is stable or not, and thus determine that whether the convergence exists certain region's economic development relative to China's economic development. Results (Table 2) show that in the 12 countries, three countries' unit root original hypothesis can be rejected at the 1% level of significance, two countries' rejected at the 5% level of significance, and four countries' at the 10% level of significance, and the other three countries can accept the unit root original hypothesis. This means that the relative real per capita output of nine countries (Japan, Malaysia, Thailand, the Philippines, Brunei, Vietnam, Laos, Myanmar, and Cambodia) of the East Asian Economic Community shows a nonlinear stable process, i.e. the nine countries' economy, relative to China's economic development, shows a nonlinear convergence with a linear trend. The other three countries (South Korea, Indonesia, and Singapore) show a diverging trend.

Table 2. Linear trend unit root

Series	lag	δ		Simulated Critical Values					
		Estimator	t -statistic	Left-tail			Right-tail		
				1%	5%	10%	1%	5%	10%
Japan ^a	2	-0.0016	-2.7122**	-3.3789	-2.0400	-1.6347	4.1965	2.6739	2.0539
Korea	1	-0.0004	-0.2454	-7.1379	-6.6258	-6.3443	2.4452	1.7326	1.4498
Malaysia ^a	2	-0.0091	-1.6653*	-2.5941	-1.9074	-1.4880	5.5756	4.1615	3.2650
Indonesia	9	-0.0144	-0.2122	-2.5000	-1.6385	-1.4029	2.2036	1.6018	1.1528
Thailand ^a	2	-0.0282	-1.9127**	-2.7890	-1.8199	-1.4894	4.9636	3.4940	2.6085
Philippines ^a	4	0.0142	1.4959*	-4.3746	-2.9526	-2.4718	3.0072	1.7994	1.4454
Singapore	1	-0.0009	-0.9022	-6.3553	-5.5856	-4.8990	3.0183	2.0290	1.5906

Brunei ^a	5	-0.0015	-3.1305***	-2.2296	-1.5521	-1.2851	2.0600	1.4884	1.2858
Vietnam ^a	3	-0.0176	-1.1214*	-2.2341	-1.4339	-0.8631	3.3448	3.1423	3.0135
Laos ^a	10	-0.1400	-3.3862***	-1.7971	-0.8569	-0.6810	1.4929	0.0945	0.0181
Myanmar ^a	1	0.0043	2.4656*	-2.5272	-1.9065	-1.5312	3.9852	2.8085	2.3160
Cambodia ^a	7	-0.2016	-2.6024***	-1.6666	-0.9289	-0.7603	1.3074	-0.0092	-0.1099

Note. ***, **, * represents the significance respectively at 1%, 5%, and 10% level. The critical value comes from the replacement residual sampling Bootstrap method. The superscript (a) represents a nonlinear convergence with a linear trend.

On the basis of nonlinear unit root test containing the linear trend, we further test the significance of trend head coefficient, namely the t value of trend head coefficient ϕ . Compare it with the critical value t derived from the Bootstrap method. If the result is significant, it is a process convergence; otherwise a long-run convergence. The test results (Table 3) show that in the nine countries showing convergence, the trend coefficients of three countries are significant at 1% level, and three countries are at 5% level, i.e. the six countries (Japan, Malaysia, Thailand, Laos, Myanmar, and Cambodia) show the nonlinear process convergence containing a linear trend, and other three countries (the Philippines, Brunei, and Vietnam) the nonlinear long-run convergence containing a linear trend.

Table 3. The trend term of linear trend

Series	lag	ϕ		Simulated Critical Values					
		Estimator	t-statistic	Left-tail			Right-tail		
				1%	5%	10%	1%	5%	10%
Japan ^b	2	-0.0056	-4.1595***	-3.6078	-2.0773	-1.7405	5.5770	3.3146	2.3163
Malaysia ^b	2	-0.0041	-2.1830**	-2.3240	-1.9322	-1.5184	6.4469	5.2189	4.3550
Thailand ^b	2	-0.0035	-2.6896**	-4.0185	-2.6307	-2.0689	3.6735	2.4270	2.0836
Philippines	4	0.0017	1.0245	-3.1724	-2.2964	-1.9067	2.5391	1.7746	1.3922
Brunei	5	-0.0045	-2.3804	-3.5836	-2.7981	-2.4641	2.3376	1.2720	0.8777
Vietnam	3	-0.0015	-1.3951	-2.3796	-1.8526	-1.5070	2.5429	1.9722	1.6336
Laos ^b	10	-0.0253	-3.0999***	-1.5434	-0.9068	-0.7291	1.1900	0.0269	-0.0469
Myanmar ^b	1	0.0128	2.2765**	-2.6748	-1.9782	-1.6218	2.7644	2.1633	1.7947
Cambodia ^b	7	-0.0343	-2.7113***	-1.5132	-0.4076	-0.2278	1.1993	0.2339	0.1224

Note. ***, **, * represents the significance respectively at 1%, 5%, and 10% level. The critical value comes from the replacement residual sampling Bootstrap method. The superscript (b) represents a nonlinear convergence with a linear trend.

3.2.3 The Unit Root Test with Nonlinear Trend Term and the Trend Term Significance Test

In the nonlinear STAR model, with intercept term and nonlinear trend term, we conduct the nonlinear unit root test on the relative real per capita output sequence of the 12 countries passing the linear test, using the method similar to the model containing the linear trend. In other words, by means of comparing the t value of nonlinear variables' head coefficient δ with the critical value t derived from the Bootstrap method, we can judge whether the real per capita output sequence of certain country is stable or not, and thus determine whether the convergence exists certain country's economic development relative to China's economic development. Test results (Table 4) show that in the 12 countries, three countries' unit root original hypothesis can be rejected at the 1% level of significance, five countries' rejected at the 5% level of significance, and two countries' rejected at the 10% level of significance, and the other two countries can accept the unit root original hypothesis. This means that the relative real per capita output of ten countries (Japan, Indonesia, Thailand, the Philippines, Singapore, Brunei, Vietnam, Laos, Myanmar, and Cambodia) of the East Asian Economic Community shows a nonlinear stable process, i.e. the ten countries' economy, relative to China's economic development, shows a nonlinear convergence with a nonlinear trend. The other two countries (South Korea and Malaysia) show a diverging trend.

Table 4. Nonlinear trend unit root

Series	lag	δ		Simulated Critical Values					
		Estimator	<i>t</i> -statistic	Left-tail			Right-tail		
				1%	5%	10%	1%	5%	10%
Japan ^c	2	-0.0021	-1.9059*	-2.9423	-2.0270	-1.7875	2.4761	1.7784	1.4528
Korea	2	-0.0022	-1.2679	-6.7250	-6.2623	-5.9936	2.5593	1.8893	1.4672
Malaysia	2	-0.0070	-1.2366	-2.9187	-1.9897	-1.6564	5.3452	4.4344	3.4205
Indonesia ^c	1	-0.0866	-3.3343**	-4.0697	-2.7329	-2.1484	2.5109	2.0058	1.6512
Thailand ^c	1	-0.0422	-2.9645***	-2.6726	-2.0017	-1.7031	2.3804	1.8398	1.5552
Philippines ^c	4	0.0133	2.1583**	-4.8810	-4.0764	-3.7579	2.3064	1.4779	1.0444
Singapore ^c	4	-0.0035	-2.9679***	-2.5574	-2.0384	-1.6114	4.5854	3.7855	3.2423
Brunei ^c	4	-0.0004	-1.0167*	-2.0590	-1.2340	-0.8850	2.6949	2.3732	2.1036
Vietnam ^c	4	-0.0483	-1.5208**	-2.1496	-1.3208	-0.9917	2.2477	1.8872	1.6011
Laos ^c	10	0.0499	1.6181**	-1.4469	-0.1190	0.0647	1.6970	0.7350	0.6223
Myanmar ^c	9	0.0040	1.8049**	-2.6444	-1.7985	-1.3913	1.8534	1.3380	1.0562
Cambodia ^c	7	-0.2479	-2.6052***	-1.4221	-0.1777	-0.0978	1.1578	0.1350	0.0694

Note. ***, **, * represents the significance respectively at 1%, 5%, and 10% level. The critical value comes from the replacement residual sampling Bootstrap method. The superscript (c) represents a nonlinear convergence with a linear trend.

On the basis of nonlinear unit root test containing the linear trend, we use the method similar to the model containing the linear trend term to further distinguish the type of convergence, namely testing the significance of trend head coefficient. Compare the *t* value of coefficient Φ with the critical value *t* derived from the Bootstrap method. If the result is significant, it is a process convergence, otherwise a long-run convergence. Test results (Table 5) show that in the ten countries showing convergence, the trend terms of six countries are significant at 1% level, two countries significant at 5% level, and one country significant at 10% level, i.e. nine countries (Japan, Indonesia, Thailand, the Philippines, Singapore, Vietnam, Laos, Myanmar, and Cambodia) show the nonlinear process convergence containing a nonlinear trend, only one country (Brunei) shows the nonlinear long-run convergence containing a nonlinear trend.

Table 5. The trend term of nonlinear trend

Series	lag	Φ		Simulated Critical Values					
		Estimator	<i>t</i> -statistic	Left-tail			Right-tail		
				1%	5%	10%	1%	5%	10%
Japan ^d	2	-0.0001	-2.6038**	-2.7565	-1.8365	-1.6034	2.9740	2.4253	2.0722
Indonesia ^d	1	-0.0001	-3.2323***	-2.6423	-1.8589	-1.4504	5.4790	4.5205	3.6080
Thailand ^d	1	-0.0001	-3.3469***	-3.1568	-2.0391	-1.6947	2.5389	1.9275	1.6917
Philippines ^d	4	0.0001	1.5662*	-5.7868	-5.0173	-4.7297	2.2806	1.6615	1.3848
Singapore ^d	4	-0.0001	-4.4113***	-2.3582	-1.5790	-1.1532	3.1787	2.7437	2.4433
Brunei ^d	4	0.0001	-0.7066	-2.6001	-2.0064	-1.7079	2.1348	1.2790	0.8834
Vietnam ^d	4	-0.0001	-1.7166**	-2.1955	-1.2198	-0.6100	3.1342	2.9137	2.6500
Laos ^d	10	0.0005	2.0464***	-1.3796	0.0000	0.3673	1.4635	0.8223	0.7769
Myanmar ^d	9	0.0003	2.1553***	-3.4007	-2.5480	-2.2579	2.0232	1.1225	0.7386
Cambodia ^d	7	-0.0029	-2.6860***	-1.2059	-0.3114	-0.2639	0.8734	-0.0497	-0.0604

Note. ***, **, * represents the significance respectively at 1%, 5%, and 10% level. The critical value comes from the replacement residual sampling Bootstrap method. The superscript (d) represents a nonlinear convergence with a linear trend.

4. The Basic Conclusion Analysis

Whether certain convergence exists in cross-national and regional long-term economic growth has always been the focus of attentions. And lots of studies on this issue have been completed. In this paper, we try to using the smooth transfer autoregressive STAR model and KSS nonlinear unit root test to conduct an empirical analysis of whether certain economic convergence exists between the 12 countries of East Asian Economic Community and China by evaluating the relative real per capita output. According to the results, the linear test indicates that the nonlinear model is capable of describing the dynamic features of all countries, while the nonlinear unit root test

indicates that a majority of countries support the nonlinear convergence. Apparently, during the long-term development process, 13 East Asian countries are gradually narrowing regional disparities through policies and economic reciprocity, stepping toward the East Asian economic integration.

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