# Examining Convergence in Per Capita Agricultural Production across Selected Asian countries

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***Abstract.*** *Since 1990s, the convergence issue has become an important field of econometric research. In recent years, a remarkable evolution of convergence literature is found in the area of agricultural economics. This article demonstrates β- and σ-convergence of per capita gross production value of agriculture (PGVA) across seventeen Asian countries from three geographical regions, i.e. South Asia, East Asia, and Southeast Asia, for the period of 1961-2011. These countries are embodied in this study because of the substantial contribution of agriculture to their economies. The data of PGVA have been created using annual gross agricultural production value divided by the total population of each country under sample and obtained from the FAOSTAT online database. The fixed effects (FE) and random effects (RE) panel data models are employed in examining β and σ-convergence. The two-way FE and RE models by adding time effects are found to be most appropriate for determining β-convergence at any level of significance. However, the empirical results of FE and RE models strongly support the σ convergence, and are highly statistically significant at any conventional levels over the examination period.*

**Keywords:** β-convergence, σ-convergence, PGVA, panel data, fixed effects, random effects.

## 1. Introduction

The neoclassical growth model as developed by Solow (1956) provides the conceptual apparatus for the convergence hypothesis which is the basis to the convergence literature in growth economics (e.g. Barro & Sala-i-Martin, 1990; Mankiw *et al*. 1992). The assumption of the Solow model, i.e. the diminishing marginal returns to capital, leads to the notion of convergence (Islam, 1995). This model refers two different ways to understand the convergence concept. First, in terms of income level, if the countries have similar preferences and technology then their steady state income levels will be the same. Second, in terms of growth rate, all countries will reach the same steady state growth rate, because the exogenous rate of technological process is the determinant of growth rate which is a public good and is shared equally between all countries.

In the last three decades, a substantial number of studies in economic growth have attempted to analyze the convergence hypothesis. Such studies are conducted by Abramovitz (1986), Arbia and Piras (2005), Barro (1991), Barro et al. (1991), Barro and Sala-i-Martin (1992), Baumol (1986), Bernard and Durlauf (1996), DeLong (1988), Freeman and Yerger (2001), Furceri (2005), Haider et al. (2010), Maurer (1995), Quah (1996), Sala-i-Martin (1996a,b), Young et al. (2008), and among others. In these studies, two interrelated concepts of convergence are discussed and empirically tested across countries or regions: first, beta ($\beta$) convergence; and second, sigma ($\sigma$) convergence. As defined in the literature, the $\beta$-convergence appears if poor economies tend to grow faster than rich economies. This notion also implies that considering other things equal the poor economies tend to catch up with the developed economies in terms of the level of per capita income or product. The $\sigma$-convergence describes a decrease of the cross-sectional dispersion in per capita income or product over time. Moreover, the economic literature (e.g. Fukuda & Toya, 1995; and Mankiw et al., 1992) often focuses on unconditional (absolute) and conditional $\beta$-convergence hypothesis. The former one indicates that each economy converges towards the same steady state income or productivity level and the later one suggests that each economy possesses its own steady-state income or productivity level when it is converging (Rezitis, 2010). However, some convergence literature (e.g. Maurer, 1995; Young et al. 2008) also discusses the causal relationship between the above concepts of convergence. For example, Furceri, (2005) examines mathematically the causal relationship between $\beta$ and $\sigma$-convergence and shows that the presence of $\beta$-convergence is necessary for the existence of $\sigma$-convergence which is similar to the finding of Barro and Sala-i-Martin (1990) and Young et al. (2008). Additionally, the study by Maurer (1995) exhibits the statistical relations between $\beta$ and $\sigma$-convergence and shows that $\sigma$-convergence implies necessarily $\beta$-convergence but that $\beta$-convergence is compatible with $\sigma$-convergence as well as $\sigma$-divergence.

Several studies of convergence in economic growth investigate convergence hypotheses across regions, countries and states and document different results. For instance, Barro et al. (1991) examine convergence considering different periods across U.S. states and 73 European regions and find strong evidence of convergence in the U.S. states. The study reports almost similar process of convergence within the European regions. The study by Sala-i-Martin (1996a) applies the concepts of σ-convergence, absolute β-convergence and conditional β-convergence to a variety of data sets such as a cross-section of 110 countries, a sub-sample of OECD economies, the states of U.S., the Japanese prefectures, and regions within several European countries. Most of the empirical results display strong evidence of σ-convergence and absolute β-convergence. The study also reports σ-divergence and conditional β-convergence across 110 countries. Moreover, a very similar speed rate of conditional convergence, i.e. 2% per year, is found across the data sets. In a cross-section of 98 countries, Barro (1991) finds that per capita growth rates have little correlation with the initial level of per capita income. Baumol (1986) reports that there is no tendency towards overall convergence, but he finds converging tendency within groups like less developed countries, OECD countries, and middle income countries. The paper by Haider et al. (2010) tests income convergence hypothesis across East and South Asian economies and finds no evidence of absolute convergence, while conditional convergence is found in both economies.

The convergence concept has spawned in agricultural economics. Consequently, numerous studies are found of investigating the convergence issue in agricultural productivity growth (e.g. total factor productivity growth) across countries or regions around the world. Such papers are published by Lusigi et al. (1998) for African countries, Martin and Mitra (1999) for 32 developing and 17 developed countries, Coelli and Rao (2003) for 93 developed and developing countries, Barrios (2007) for 27 Asian countries, Rezitis (2010) for the United States (US) and the European Union (EU), Poudel et al. (2011) for the states of US, Liu et al. (2011) for the states of US, Suharianto and Thirtle (2001) for Asian countries, Galanopoulos et al. (2006) for Mediterranean countries, and Alexiadis (2010) for European regions. The present article differs from the previous studies in terms of the countries included in the sample and the variables used for testing convergence. Most of the existing papers test the convergence hypothesis of agricultural productivity growth, while this paper tests the convergence in per capita gross production value of agriculture to investigate whether the countries with relatively low initial levels of per capita gross production value of agriculture grow faster than higher ones and whether the dispersion of per capita gross production value of agriculture across countries shows a tendency to decline over time.

Agricultural production is the only source of food supply and food security. Therefore, maintaining of agriculture production level is necessary to meet the food demand and the food security of the growing population in the world. The study of Funk and Brown (2009) reports that if the growing pattern of agricultural yields run more slowly than the per capita harvested area, Asia and other regions in the world will face remarkable decrease in per capita cereal production. This study also argues that 14% of global per capita cereal production will decline between 2008 and 2030. Most of the developing countries in Asia, particularly SAARC (South Asian Association of Regional Cooperation) countries, are predominantly aided by the agricultural sector and classified as low income or middle low income category. The agricultural sector of these countries is not developed. The reasons behind this are high dependency on manual production system, slow adoption of modern technology, and facing natural threats like warming in the tropical Ocean and its impact on rainfall. On the other hand, most of the countries in East Asia and Southeast Asia, particularly ASEAN countries (Association of Southeast Asian Nations), adopt promptly the modern agro-technology and show substantial development in agricultural production.

The objective of the present paper is to test convergence in per capita gross production value of agriculture for selected seventeen Asian countries, i.e. Bangladesh, Cambodia, China, India, Indonesia, Japan, Laos, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippine, Korea Rep., Sri Lanka, Thailand, and Vietnam over the period 1961-2011. To this end, this study utilizes annual data of gross production value of agricultural and total population, and then it calculates the per capita gross production value of agriculture. This paper employs panel data fixed effects and random effects estimators for investigating convergence. These approaches are used because of advanced benefits over cross-section and time series models such as they allow controlling for heterogeneity that affects the behavior of the cross-sectional units (Islam, 1995; Hsiao, 2003).

The rest of this article is constructed as follows. In section 2, the methodology for convergence test is incorporated. Section 3 describes the data. Estimated results are reported in section 4. Finally, section 5 concludes.

## 2. Methodology

The economic convergence papers, e.g. Hossain (2000), Haider et al. (2010) and among others, examine two convergence hypotheses, i.e. $\beta$ and $\sigma$-convergence. $\beta$-convergence refers that countries with relatively weak starting level of productivity, defined in this study as per capita gross production value of agriculture (PGVA), grow relatively faster than countries with higher PGVA. Empirically, a cross-sectional regression refers to the absolute $\beta$-convergence if the coefficient of the initial level of PGVA bears a negative sign when its level is regressed by the annual growth rate of PGVA. Thus, a test of $\beta$-convergence is performed by running the following regression:

$$\hat{y}_{it} = \alpha + \beta\, pgva_{i,t-1} + \varepsilon_{it} \quad (i = 1,....,N)\ (t = 1,....,T) \quad \text{..........................................} (1)$$

where $\hat{y}_{it}$ denotes the annual growth rate of PGVA for country $i$ at time $t$, $pgva_{i,t-1}$ indicates the log (PGVA) level for country $i$ at time $t-1$, $\alpha$ and $\beta$ are parameters and $\varepsilon_{it}$ is a disturbance term with zero mean and finite variance. In terms of equation (1) a significant negative value of $\beta$ indicates absolute (unconditional) $\beta$-convergence, i.e. $\beta < 0$, while $\beta \geq 0$ implies non-convergence.

For evidence of $\sigma$- convergence across countries, an essential condition is that the cross-sectional disparities in the growth of PGVA decrease over time. The following regression model can be estimated for testing $\sigma$-convergence:

$$SD(pgva_t) = \phi_1 + \phi_2 t + \varepsilon_t \quad (t = 1,....,T) \quad \text{....................................................} (2)$$

where $SD(pgva_t)$ is the standard deviation of $pgva_t$ across countries at time $t$, $t$ is the time trend, $\phi_1$ and $\phi_2$ are parameters and $\varepsilon_t$ is a disturbance term with zero mean and finite variance. A statistically significant negative value of $\phi_2$ signifies $\sigma$-convergence to the same $pgva_t$ level for all countries.

Having a balanced panel data set, this paper applies a set of panel data techniques for estimating convergence models, i.e. equation (1) and equation (2). These techniques are pooled ordinary least square (OLS) model, fixed effects model (FEM) and random effects model (REM).

The pooled OLS model, called constant coefficient model, assumes that both the intercepts and slope coefficients are the same (constant across countries and time) for all 17 countries in the sample. This model ignores the country-specific effects and time-effects during estimation convergence models, i.e. equations (1) and (2). Thus, the pooled OLS regression indicates $\alpha, \beta = \alpha_{it}, \beta_{it}$ for beta convergence model, i.e. equation (1), and $\phi_1, \phi_2 = \phi_{1it}, \phi_{2it}$ for sigma convergence model, i.e. equation (2). So, this estimation procedure is highly restrictive which may disfigure the true picture of the relationship between $\hat{y}_{it}$ and $pgva_{i,t-1}$ in the beta convergence model and between $SD(pgva_t)$ and $t$ (time trend) in the sigma convergence model. Thus simply running pooled OLS would lead to biased and inconsistent estimation results. As studies commonly applied, the FEM and REM could remedy the shortcomings of pooled OLS estimator. The FEM and REM estimators allow for heterogeneity across countries (and possibly across time) but they confine the heterogeneity to the intercept terms.

In the FEM, the country-specific effect is a random variable that is correlated with explanatory variables but uncorrelated with error term. This approach assumes that slopes are constant but intercepts vary across countries. Thus the forms of the convergence models are

$\hat{y}_{it} = \alpha_i + \beta pgva_{i,t-1} + \varepsilon_{it} \; (i = 1, ...., N) \; (t = 1, ...., T)$ ……………………………………. (3)

and

$[SD(pgva_t)]_{it} = \phi_{1i} + \phi_2 t_{it} + \varepsilon_{it} \quad (i = 1, ...., N) \; (t = 1, ...., T)$ ……………………………… (4)

where $\alpha_i$ and $\phi_{1i}$ $(i = 1, ...., N)$ in equation (3) and (4) respectively are unknown intercepts and indicates unobserved country-specific effects and $\varepsilon_{it}$ is stochastic errors with $IID(0, \sigma_\varepsilon^2)$. The $\alpha_i$ $(i = 1, ...., N)$ are correlated with $pgva_{i,t-1}$ but uncorrelated with $\varepsilon_{it}$ in the equation (3) and the $\phi_{1i}$ $(i = 1, ...., N)$ are correlated with $t_{it}$ but uncorrelated with $\varepsilon_{it}$ in the equation (4). The $pgva_{i,t-1}$ and $\phi_{1i}$ are assumed independent of the $\varepsilon_{it}$ for all $i$ $(i = 1, ...., N)$ and $t$ $(t = 1, ...., T)$. The FEM is estimated with the least square dummy variable (LSDV) estimation technique which is numerically same to pooled OLS estimation technique by including a set of $N-1$ dummy variables which identify the countries. It is noted that one of the country dummies has to be dropped if a constant is included. For estimating time-specific effects one can extend the models by including a set of $T-1$ dummy variables. One of the time dummies has to be dropped to avoid perfect collinearity.

In the REM, the country-specific effect is a random variable which has zero correlation with the explanatory variables and the overall error term. This model allows the random country-specific effect to enter the equations (1) and (2) through the error term. Thus the convergence models (1) and (2) are remodeled as

$\hat{y}_{it} = \alpha + \beta pgva_{i,t-1} + (u_i + \varepsilon_{it})$ ............................................................ (5)

and

$[SD(pgva_t)]_{it} = \phi_1 + \phi_2 t_{it} + (u_i + \varepsilon_{it})$ ........................................................... (6)

In both equations (5 and 6), $(u_i + \varepsilon_{it})$ is a composite error term which is composed of two statistically independent components, one is $u_i$ associated with unobserved country-specific effects with $IID(0, \sigma_u^2)$ and the other component, $\varepsilon_{it}$, is the remainder error with $IID(0, \sigma_\varepsilon^2)$. The $u_i$ are independent of the $\varepsilon_{it}$. In addition, $pgva_{i,t-1}$ and $t_{it}$ are independent of the $u_i$ and $\varepsilon_{it}$, for all $i$ $(i = 1,...., N)$ and $t$ $(t = 1,...., T)$. The REM treats the $u_i$'s $(i = 1,...., N)$ not as country constants but as random errors associated with the $i^{th}$ country. It is assumed that the $u_i$ $(i = 1,...., N)$ are uncorrelated with $pgva_{i,t-1}$ and $\varepsilon_{it}$ in the equation (5) and with $t_{it}$ and $\varepsilon_{it}$ in the equation (6). For estimating the parameters of the equation (5) and equation (6), the generalized least squares (GLS) is an usual estimator.

This study utilizes the Hausman test and the Breusch-Pagan Lagrange multiplier (LM) test for model specification. Hausman test is commonly used to choose between fixed or random effect where the null hypothesis is that the REM is preferred against the FEM. Breusch-Pagan Lagrange multiplier (LM) test helps to choice between the REM and the pooled OLS model. The null hypothesis of this test is that variances across countries are zero. That means there is no significant difference across countries (i.e. no panel effect). Beside these, a set of diagnostic tests is applied for testing the validity and reliability of the models. First, $F$ (or Chow) test is used for testing the significance of the country-specific effects where the null hypothesis is that the constant terms are all equal across countries. The rejection of the null hypothesis of this test indicates that the pooled OLS model is inconsistent against FEM. Second, a joint test of the significance of time fixed effects is used to see if time fixed effects are needed when running a FEM. The null hypothesis of this test is that the coefficients of all yearly dummies are jointly equal to zero. Third, Pesaran's cross-sectional dependence (CD) test is used for FEM for testing cross-sectional dependence or contemporaneous correlation where the null hypothesis is that residuals are uncorrelated across countries. Fourth, the modified Wald statistic is used for testing heteroskedasticity in the FEM where the null hypothesis is homoscedasticity (or constant variance) of $\varepsilon_{it}$ across countries of the panel. Finally Wooldridge test is used for testing serial correlation where the null hypothesis is no serial correlation in the panel data.

## 3. Data

This study investigates the convergence hypothesis of selected East, South and Southeast Asian countries. The sample consists of 17 countries where among the South Asian countries are Bangladesh, India, Nepal, Pakistan and Sri Lanka, among the East Asian countries are China, Japan, Mongolia, and Republic of Korea, and among the Southeast Asian countries are Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippine, Thailand, and Vietnam. Annual gross production value of agriculture and annual total population for the aforementioned countries over the period from 1961 to 2011 are obtained from FAOSTAT online database accessed on 22 March, 2013 (http://faostat3.fao.org/home/index.html#DOWNLOAD). Per capita gross production value of agriculture (PGVA) is created by dividing the annual gross production value of agriculture by annual total population. Then, the log (PGVA) is created ($pgva$) and used for the estimation of models for testing for $\beta$- and $\sigma$-convergence. As FAOSTAT indicates, gross production value has been compiled by multiplying gross production (including seed and feed) in physical terms by output prices at farm gate. Value of gross production is provided in constant (2004-2006) term and is expressed in US dollars. Annual total population includes both sexes – male and female of each country.

## 4. Results

The two basic convergence models, i.e. (1) and (2), are estimated in order to investigate $\beta$ and $\sigma$-convergence of per capita gross production value of agriculture across the seventeen Asian countries during the period 1961-2011. Since the data used in this paper are both cross-sectional and time series, a set of panel data estimators (i.e. pooled OLS, fixed effects, and random effects) is utilized for estimating the regression equations (1) and (2). Initially, a pooled OLS regression is used for estimating both convergence models (equation 1 and 2) and their estimation results are reported in Table 1 and 2 respectively. Then, the basic convergence models (equation 1 and 2) are reformulated based on FEM as in equations (3) and (4) and the estimation results are also shown in Table 1 and 2 respectively. Finally, the models (i.e. equations 1 and 2) are rearranged as in equations (5) and (6) based on REM and their estimated results are incorporated in Table 1 and 2 respectively. A number of diagnostic tests described in the methodology section is performed and their results also are reported in Table 1 and 2 respectively. Hausman test and Breusch-Pagan LM test are used for model specification and these tests results are shown in the Table 3. The econometric analysis is conducted using the STATA 12.0 version software.

**Table 1.** Empirical results of $\beta$-convergence models

| Models | Variables | Coefficient | Stand. Errors | t-statistics | p-value | $R^2$ | Model Test [a] |
|---|---|---|---|---|---|---|---|
| OLS | α | 0.0505611 | 0.0350314 | 1.44 | 0.149 | 0.0027 | 2.33 [0.1270] |
| | β | -0.007735 | 0.006593 | -1.17 | 0.241 | | |
| One-way fixed effects | α | 0.0866827 | 0.0742519 | 1.17 | 0.260 | Within = 0.0031 Between = 0.0249 Overall =0.0027 | 1.06 [0.3189] |
| | β | -0.0146761 | 0.0142671 | -1.03 | 0.319 | | |
| | sigma_u | 0.01117373 | - | - | | | |
| | sigma_e | 0.06275406 | - | - | | | |
| | rho | 0.03072967 | - | - | | | |
| | corr (u_i, Xb) | -0.2733 | - | - | | | |
| | Diagnostic Tests Value [p-value]<br>Test for fixed effects ($F$ or Chow test) 1.47 [0.1050]<br>Pesaran CD test 3.19 [0.0002]<br>Test for heteroskedasticity (Wald test) 1555.2 [0.0000]<br>Wooldridge test for serial correlation 95.965 [0.0000] | | | | | | |
| Two-way Fixed effects | α | 0.2339131 | 0.0631883 | 3.70 | 0.000*** | Within = 0.1024 Between = 0.0249 Overall =0.0710 | 1.79 [0.0009]*** |
| | β | - 0.042954 | 0.0111094 | -3.87 | 0.000*** | | |
| | sigma_u | 0.01754067 | - | - | - | | |
| | sigma_e | 0.06138264 | - | - | - | | |
| | rho | 0.07549377 | - | - | - | | |
| | corr (u_i, Xb) | -0.4855 | - | - | - | | |
| | Diagnostic Tests Value [p-value]<br>Test for time fixed effects 1.77 [0.0012] | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pesaran CD test - 3.00 [0.0027]<br>Test for heteroskedasticity (Wald test) 843.75 [0.0000] | | | | | | |
| One-way Random Effects | α | 0.0554756 | 0.0449556 | 1.23 | 0.217 | Within = 0.0031 Between = 0.0249 Overall =0.0027 | 0.95 [0.3308] |
| | β | -0.0086798 | 0.0089248 | -0.97 | 0.331 | | |
| | sigma_u | 0.00632391 | - | - | - | | |
| | sigma_e | 0.06275406 | - | - | - | | |
| | rho | 0.01005309 | - | - | - | | |
| | corr (u_i, X) | 0 (assumed) | - | - | - | | |
| Two-way Random Effects | α | 0.0877769 | 0.0375167 | 2.34 | 0.019** | Within = 0.0961 Between = 0.0249 Overall =0.0896 | 80.78 [0.0038]*** |
| | β | -0.0165173 | 0.0062177 | -2.66 | 0.008*** | | |
| | sigma_u | 0.00658762 | - | - | - | | |
| | sigma_e | 0.06138264 | - | - | - | | |
| | rho | 0.01138655 | - | - | - | | |
| | corr (u_i, X) | 0 (assumed) | - | - | - | | |

Notes: ** and *** indicate statistically significant at 5% and 1% level respectively. The coefficient $\alpha$ is intercept and $\beta$ is the coefficient of the initial level of $pgva$. Number of observations used in computation = 850. [a] F-test/ Wald test is used as of the model test. The values in the brackets are also p-value.

In the above Table 1, the result from pooled OLS shows that the estimated value of $\beta$ coefficient is negative which favors the stipulation of unconditional $\beta$-convergence, but this result is statistically insignificant. So, the statistical inference for occurring unconditional convergence in per capita gross production value of agriculture across the sample countries is not possible. The model test ($F$ test) result also implies that the pooled OLS estimation is an inadequate model. The estimation results of the one-way fixed effects model indicate the same inferences as the pooled OLS result. According to the empirical results of the two-way fixed effects, i.e. adding time effects with FEM, the $\beta$ coefficient is still negative and statistically significant at any conventional levels and the model test, i.e. $F$-test, supports statistically the two-way estimation at any conventional levels of significance. So, there is a strong evidence of unconditional $\beta$-convergence in per capita gross production value of agriculture across the selected Asian countries in the sample during 1961-2011. However, the estimation results of the one-way REM draw almost the same inference as the one-way FEM results. But the estimation results of two-way REM indicate a negative value of $\beta$ coefficient which is statistically significant at any conventional levels. The result of model test, i.e. $F$ test, is also statistically significant at any conventional levels. So, the results of two-way REM show the evidence in favor of the unconditional $\beta$-convergence (this inference supports the two-way FEM). Thus, although the results of pooled OLS, one-way FEM and REM do not show the clear evidence of unconditional convergence, in general, the results indicate unconditional $\beta$-convergence in per capita gross production value of agriculture among the sample countries. In other words, countries with initially low level of per capita gross production value of agriculture (PGVA) grow faster than countries with initially high level of PGVA.

Table 1 also shows that the diagnostic $F$ (or Chow) test for one-way FEM rejects the null hypothesis, i.e. the constant terms are equal across countries, at around 10% level of significance. Thus, the fixed effects model gets the preference over the pooled OLS model. A joint test is performed for two-way FEM to see if time fixed effects are needed when running a FEM. This test rejects the null hypothesis, i.e. all coefficients of year dummies are jointly equal to zero, and significant at any conventional level and conclude that time fixed effects are needed when running FEM to estimate beta convergence model. In both FEMs, the test for cross-sectional dependence using Pesaran's CD test rejects the null hypothesis, i.e. residuals are not correlated, and supports the presence of cross-sectional dependence in the panel data at any conventional level of significant. The test for heteroskedasticity is performed for both FEMs which rejects the null hypothesis of homoskedasticity at any conventional level of significance. Therefore, heteroskedasticity problem exists in the panel data. Finally, the Wooldridge test rejects the null hypothesis of no serial correlation at any conventional level of significance and concludes that there is serial correlation in the panel data.

The estimated results of pooled OLS, FEM and REM for $\sigma$-convergence model are reported in Table 2. According to the empirical findings, all the estimators report that the value of parameter $\phi_2$ is negative and statistically significant at any conventional level. Moreover, the model tests ($F$ test) imply that each estimator is statistically significant at any conventional level. It is noted that the two-way FEM and REM have more explanatory power (overall $R$-square) than others. Additionally, Figure 1 shows the actual and fitted values of the dependent variable ($SD(pgva)$) of regression equation (2) for the period 1961-2011 and indicates a negative slope of the fitted values over the period. A visual inspection of the actual values indicates some fluctuation and a decline

**Table 2.** Empirical results of $\sigma$-convergence models

<table>
<tr><th>Models</th><th>Variables</th><th>Coefficient</th><th>Stand. Errors</th><th>t-statistics</th><th>p-value</th><th>$R^2$</th><th>Model Test [a]</th></tr>
<tr><td rowspan="2">OLS</td><td>$\phi_1$</td><td>0.4382242</td><td>0.0015103</td><td>290.16</td><td>0.000***</td><td rowspan="2">0.2843</td><td rowspan="2">343.54 [0.0000]</td></tr>
<tr><td>$\phi_2$</td><td>-0.0009369</td><td>0.0000505</td><td>-18.53</td><td>0.000***</td></tr>
<tr><td rowspan="7">One-way fixed effects</td><td>$\phi_1$</td><td>0.4382242</td><td>0.0015244</td><td>287.47</td><td>0.000***</td><td rowspan="6">Within = 0.2843 Between =0 Overall =0.2843</td><td rowspan="6">337.19 [0.0000]</td></tr>
<tr><td>$\phi_2$</td><td>-0.0009369</td><td>0.000051</td><td>-18.36</td><td>0.000***</td></tr>
<tr><td>sigma_u</td><td>0.00006638</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>sigma_e</td><td>0.02211409</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>rho</td><td>9.009e-06</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>corr (u_i, Xb)</td><td>0.0000</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td colspan="7">Diagnostic Tests Value [p-value]<br><br>Test for fixed effects ($F$ or Chow test) 21.07 [0.0000]<br>Pesaran CD test 83.245 [0.0000]<br>Test for heteroscadasticity (Wald test) 0.01 [0.0000]<br>Wooldridge test for serial correlation 23338.823 [0.0000]</td></tr>
<tr><td rowspan="7">Two-way Fixed effects</td><td>$\phi_1$</td><td>0.4660249</td><td>0.0001195</td><td>3900.50</td><td>0.000***</td><td rowspan="6">Within = 0.9997 Between =0 Overall =0.9997</td><td rowspan="6">51915.89 [0.0000]</td></tr>
<tr><td>$\phi_2$</td><td>-0.0020062</td><td>4.55e-06</td><td>-440.59</td><td>0.000***</td></tr>
<tr><td>sigma_u</td><td>0.00006638</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>sigma_e</td><td>0.00047403</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>rho</td><td>0.01923077</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>corr (u_i, Xb)</td><td>0.0000</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td colspan="7">Diagnostic Tests Value [p-value]<br><br>Test for time fixed effects 37692.77 [0.0000]<br>Pesaran CD test 63.687 [0.0000]</td></tr>
</table>

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Test for heteroscadasticity (Wald test) 3749.35 [0.0000] | | | | | | |
| One-way Random Effects | $\phi_1$ | 0.4382242 | 0.0015103 | 290.16 | 0.000*** | Within = 0.0000 Between =0.0000 Overall =0.2843 | 343.54 [0.0000] |
| | $\phi_2$ | -0.0009369 | 0.0000505 | -18.53 | 0.000*** | | |
| | sigma_u | 0 | - | - | - | | |
| | sigma_e | 0.02211409 | - | - | - | | |
| | rho | 0 | - | - | - | | |
| | corr (u_i, X) | 0 (assumed) | - | - | - | | |
| Two-way Random Effects | $\phi_1$ | 0.4207998 | 0.0001244 | 3383.50 | 0.000*** | Within = 0.0000 Between =0.0000 Overall =0.9997 | 2.58e+06 [0.0000] |
| | $\phi_2$ | -0.0002667 | 4.74e-06 | -56.24 | 0.000*** | | |
| | sigma_u | 0 | - | - | - | | |
| | sigma_e | 0.00047403 | - | - | - | | |
| | rho | 0 | - | - | - | | |
| | corr (u_i, X) | 0 (assumed) | - | - | - | | |
| Notes: *** indicates statistically significant at any conventional level. The coefficient $\phi_1$ is intercept and $\phi_2$ is the coefficient of the time trend. Number of observations used in computation = 867. [a] F-test/ Wald test is used as of the model test. The values in the brackets are also p-value. | | | | | | | |

of the ( $SD(pgva)$ ) during the period, 1961-2011. Thus, $\sigma$-convergence test results

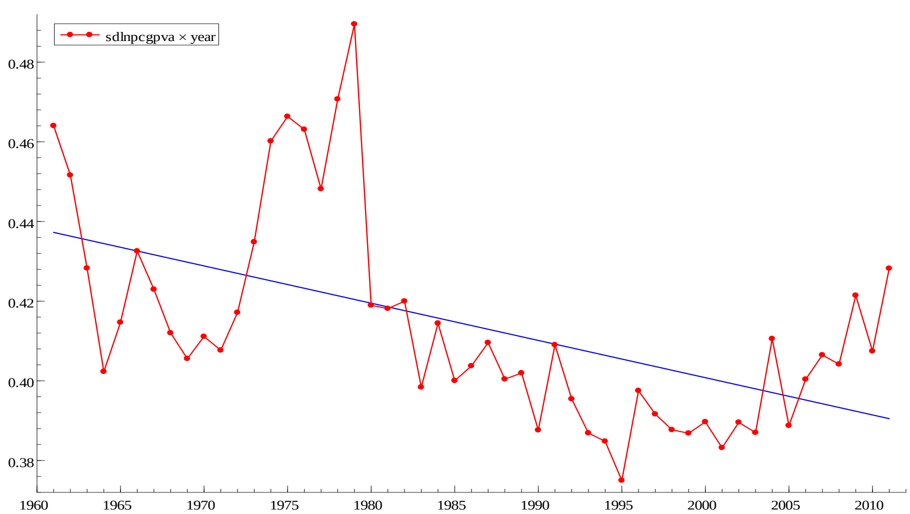


**Figure 1. SD ( $pgva$ ) for the period 1961-2011**

indicate that the PGVA growth rates converge across the selected Asian countries over the period considered in this study.

Table 2 also reports some diagnostic tests such as the $F$ (Chow) test. For one-way FEM this test tests the null hypothesis that the constant terms are equal across countries which is rejected at any conventional level of significance. Thus, the fixed effects model gets the preference over the pooled OLS model. A joint test is performed for two-way FEM to see if time fixed effects are needed when running a FEM. This test also rejects the null hypothesis, i.e. all coefficients of year dummies are jointly equal to zero, at any conventional level of significance and conclude that time fixed effects are needed when running FEM to estimate sigma convergence model. For both FEMs, the Pesaran's CD test rejects the null hypothesis, i.e. residuals are not correlated, at any conventional significant level and concludes the presence of cross-sectional dependence in the panel data. The test for heteroskedasticity is performed for both FEMs which is failed to be rejected the null hypothesis and concludes homoscedasticity in the panel data. Finally, the Wooldridge test is used for checking the autocorrelation in the panel data which rejects the null hypothesis at any conventional level of significance and reports the presence of serial correlation.

Table 3 shows that for both convergence models the Hausman statistic tests the null hypothesis that the unobserved country-specific effects are uncorrelated with the explanatory variables, i.e. tests the REM against the FEM and supports the REM. In case of both convergence models, the Breusch-Pagan Lagrange multiplier (LM) test failed to reject the null hypothesis, i.e. variances across countries is zero ($\sigma_u^2 = 0$), and conclude that random effects regression is not appropriate. This is no evidence of significance differences across countries; therefore a simple OLS regression could be run.

**Table 3** Model specification tests

| Tests | β-conv. model, Eq. (1) | σ-conv. model, Eq. (2) |
|---|---|---|
| Hausman test | 0.74 [0.3910] | 0.00 [1.0000] |
| Breusch-Pagan LM test for random effects | 0.99 [0.1603] | 0.00 [1.0000] |
| Note: The values in brackets are p-values. | | |

The empirical results of convergence tests show the evidence of both $\beta$ - and $\sigma$ - convergence over the investigation period. It is worth stating that $\beta$ and $\sigma$-convergence are related measure, though they are differently tested. A necessary condition for $\sigma$-convergence is the existence of $\beta$-convergence (Sala-i-martin, 1996b).

## 5. Conclusion

This paper investigates $\beta$- and $\sigma$-convergence in per capita gross production value of agriculture across the selected seventeen Asian countries over the period 1961-2011. The panel data techniques, i.e. pooled OLS, fixed effects and random effects models, are used for estimating the two basic convergence models. The test results of $\beta$-convergence model, i.e. equation (1), indicate that the countries have low initial level of per capita gross production value of agriculture grow faster than the countries with high starting level of per capita gross production value of agriculture. Thus, there is an evidence of unconditional beta convergence in the per capita gross production value of agriculture across the sample countries over the period. The test results of $\sigma$ - convergence model indicate that the cross-sectional dispersion in per capita gross production value of agriculture levels decrease over time. So, there is a strong evidence of sigma convergence across the sample countries over the investigation period.

The future research will may consider conditional convergence tests to know the particular factor(s) which influence the convergence process in per capita agricultural production of the selected countries. The further research may be explored to the long-run or stochastic convergence test. In addition, the present test results may be justified by the semi-parametric and non-parametric approaches. As a final note, the analysis of convergence in per capita agricultural production is important adopting different Asian countries because of contributing a large portion (about 50% of total world production) of agricultural production to meet the incremental demand of agricultural commodities in the world.

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