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Sectoral Analysis of Energy Productivity Convergence: Empirical Evidence from Asian Countries

Dipa Adhikari, Yanying Chen

School of Economics, Dalian University of Technology, Dalian, China
Email: dipadhikari@hotmail.com, yychen@dlut.edu.cn

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Abstract

This study examines the convergence of energy productivity at the sectoral level across 35 Asian countries from 1991 to 2011 by using the spatial panel data approach. The results reveal that mixed evidence of convergence process in the sectoral energy productivity for these 35 Asian countries. We found beta-convergence process exists in energy productivity in the construction, manufacturing, mining; manufacturing and utilities, transport; storage and communications, and wholesale; retail trade; restaurants and hotels sectors. While there is no evidence of energy productivity convergence in the agriculture; hunting; forestry and fishing sector over the study period. Moreover, the spatial spillover effect has a positive impact on the sectoral energy productivity growth in 35 Asian countries.

Keywords

Convergence, Energy Productivity, Sectoral Approach, Spatial Panel Data Models, Asian Countries

1. Introduction

Over the last twenty five years, several studies have attempted to analyze the convergence from diverse economic aspects in different countries or regions. Most of the prior studies have been focused on income convergence[1]. In the twenty one century, enormous researchers have examined the convergence of energy-related issues such as carbon-dioxide emissions (e.g., Strazicich and List [3]; Aldy [4]; Romero-Avila [5]; among others), energy use (e.g., Jakob *et al*. [6]; Mohammadi and Ram [7]; Meng *et al*. [8]), electricity intensity (e.g., Maza and Villaverde [9]; Liddle [10]). Specifically, some recent studies have highlighted a convergence analysis of

[1]See Islam [1] and Abreu *et al*. [2] provided a detailed literature survey of this issue.

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energy intensity or productivity in energy-economics literature (e.g., Markandya *et al*. [11]; Ezcurra [12]; Le Pen and Sevi [13]; Liddle [14]; Duro and Padilla [15]). These studies typically examined the energy intensity or productivity convergence at the aggregate level. However, few studies have also highlighted the convergence of energy productivity or intensity at the sectoral level (e.g., Miketa and Mulder [16]; Mulder and De Groot [17]; Mulder and de Groot [18]; Mulder *et al*. [19]). These studies have only focused on two individual sectors: manufacturing sector and services sector.

A review of the above cited papers has not dealt with the spatial effects of energy productivity convergence at both the aggregate and sectoral levels. Nevertheless, very few authors have basically focused on convergence of energy intensity or productivity by using the spatial panel data model. Yu [20] applied the spatial panel data model to study the influential factors of China's regional energy intensity from 1988 to 2007. The author found a remarkable spillover effect between eastern and western China and an existence absolute beta-convergence of provincial energy intensity. Likewise, Adhikari and Chen [21] used a spatial panel data approach to investigate the energy productivity convergence in Asian countries during the period 1993-2010 and found mixed evidence of beta-convergence process in energy productivity. These two more recent studies have mainly concentrated at the aggregate level of energy productivity or intensity convergence.

Additionally, Mulder *et al*. [22] examined a spatial perspective on global energy productivity trends at both the macroeconomic and sectoral levels and their finding shown that cross-country difference of energy productivity development has largely influenced by the spatially weighted average of the energy productivity growth rates of its neighboring countries. Wan *et al*. [23] conducted a study on the trade-facilitated spillovers in convergence of energy productivity at the disaggregated manufacturing sectors applying a spatial panel data method across 16 European Union countries over the period 1995-2005. They found a strong evidence of convergence in energy productivity in European Union countries. However, earlier studies on convergence of energy productivity using the spatial panel data model are highly limited at the sectoral level, particularly in Asia. For this reason, our study incorporates the spatial effect of sectoral energy productivity convergence across Asian countries.

The main goal of this study is to investigate the energy productivity convergence at the sectoral level among Asian countries by using the spatial panel data approach. This paper incorporates six main economic sectors, namely, agriculture; hunting; forestry and fishing sector, construction sector, manufacturing sector, mining; manufacturing and utilities sector, transport; storage and communications sector, and wholesale; retail trade; restaurants and hotels sector covering the period 1991-2011. To the best of our knowledge, the spatial panel data models have not been applied by earlier studies, particularly in Asian countries at the sectoral level.

The remainder of this article is organized as follows. Section 2 describes the data sources and methodology used in this study. Section 3 provides the results and discussion of the study. Section 4 presents the conclusions.

2. Data and Methodology

2.1. Data

We use a balanced panel data of 35 Asian countries at the sectoral level covering the period from 1991 to 2011. The investigation sample countries consist of Bahrain, Bangladesh, Brunei, China, Hong Kong, India, Indonesia, Iran, Iraq, Israel, Japan, Jordan, Kazakhstan, Kyrgyz Republic, Lebanon, Malaysia, Mongolia, Nepal, Oman, Pakistan, Philippines, Qatar, Saudi Arabia, Singapore, South Korea, Sri Lanka, Syrian Arab Republic, Tajikistan, Thailand, Turkmenistan, Turkey, United Arab Emirates, Uzbekistan, Vietnam, and Yemen. We measure here energy productivity concept as the ratio of gross value added to energy use, *i.e.*, inverse of energy intensity. The annual data of energy use (kg of oil equivalent per capita) and gross value added in constant 2005 US dollars are collected from the World Development Indicators (WDI, 2013, http://data.worldbank.org/) and United Nations Statistics Division National Accounts (UN, 2013, http://data.un.org/), respectively. The sectoral level is additionally divided into six sectors: agriculture; hunting; forestry and fishing sector, construction sector, manufacturing sector, mining; manufacturing and utilities sector, transport; storage and communications sector, and wholesale; retail trade; restaurants and hotels sector. All variables are converted into natural logarithms and the length of the study period and countries are dictated according to the data availability of energy use and gross value added. Geographic information of these 35 Asian countries is taken from maps of World (see, www.mapsofworld.com).

Table 1 presents the summary statistics of energy productivity for six sectors during the period 1991-2011. Among six sectors, the mining; manufacturing and utilities sector has the greatest average annual growth rates of energy productivity (16.12).

Figure 1 displays the log of energy productivity for each sector from 1991 to 2011. The figure demonstrates the construction sector, manufacturing sector, mining; manufacturing and utilities sector, transport; storage and communications sector, and wholesale; retail trade; restaurants and hotels sector energy productivity trend is increasing throughout the study period. However, the agriculture; hunting; forestry and fishing sector remains stable during the study period, which implies that lack of economic progress and technology transfer in this sector.

2.2. Methodology

In the present study, we used two most commonly and widely well-known convergence concepts such as sigma-convergence and beta-convergence (Barro & Sala-i-Martin [24] [25]). The sigma-convergence (see for example, Fan and Casetti [26]; Bernard and Jones [27]) that measures the disparity of productivity of the given time period can be calculated by applying the standard deviation or coefficient of variation. The standard deviation of sectoral energy productivity herein is calculated by Equation (1):

$$\sigma_t = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\ln EP_{it} - \ln \overline{EP_t}\right)^2} \tag{1}$$

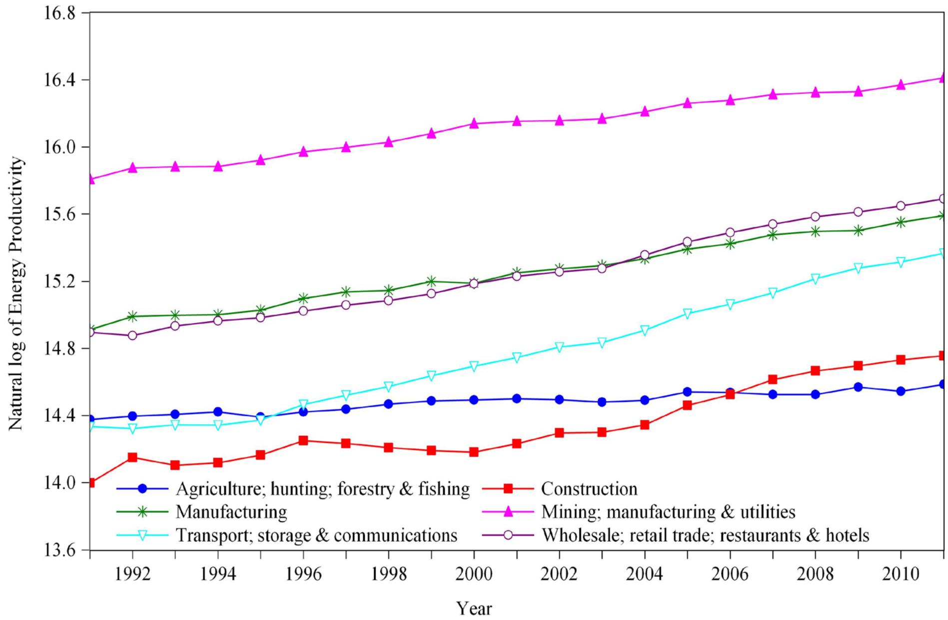

Figure 1. Energy productivity at the sectoral level for Asian countries from 1991 to 2011. Sources: World Bank (World Development Indicators (WDI), 2013, http://data.worldbank.org/) and United Nations Statistics Division National Accounts (United Nations (UN), 2013, http://data.un.org/).

Table 1. Summary statistics.

Sectors	Mean	Maximum	Minimum
Agriculture; hunting; forestry & fishing	14.4807	19.5547	7.6245
Construction	14.3444	18.8627	9.9265
Manufacturing	15.2517	20.4249	9.6787
Mining; manufacturing & utilities	16.1222	20.6142	12.5304
Transport; storage & communications	14.7756	19.1433	9.4830
Wholesale; retail trade; restaurants & hotels	15.2497	19.6848	10.1592

Sources: World Bank (World Development Indicators (WDI), 2013, http://data.worldbank.org/) and United Nations Statistics Division National Accounts (United Nations (UN), 2013, http://data.un.org/).

where, EP_{it} = energy productivity, $\overline{EP_t}$ = average value of the energy productivity of the specified time period, and N = total number of countries.

The beta-convergence approach (Barro and Sala-i-Martin [24] [25]) that is commonly used today in the macro-economic community was originally derived from the neoclassical Solow-Swan growth theory (Solow [28]; Swan [29]). In this study, we used the absolute beta-convergence model of Barro and Sala-i-Martin [24] [25] to analyse the sectoral energy productivity convergence in Asia. The absolute beta-convergence model can be expressed as follows:

$$\ln\left(EP_{i,t+1}/EP_{it}\right) = a + \beta \ln EP_{it} + \varepsilon_{it} \tag{2}$$

where i, and t denote the countries and time period, a is the intercept and ε_{it} is the error term. $\ln(EP_{i,t+1}/EP_{it})$ = natural logarithm of the average growth rate of energy productivity, and $\ln EP_{it}$ = natural logarithm of the initial levels of energy productivity. The coefficient of $\beta \ln EP_{it}$ is statistically significant and negative sign gives the existence of beta-convergence hypothesis (Baumol [30]).

In recent years, the convergence models that add the spatial effect have been applying in the macroeconomic growth literature (e.g., Abreu *et al*. [31]; Rey and Montouri [32]). For this study, we used the spatial panel econometric models to investigate the convergence of energy productivity at the sectoral level in Asian countries. The spatial panel econometric methods could be applied in different ways of spatial effects such as the spatial lag panel data model (SAR) and the spatial error panel data model (SEM).

The spatial lag panel data model with absolute beta-convergence model can be defined in Equation (3):

$$\ln\left(EP_{i,t+1}/EP_{it}\right) = \alpha + \sum_{j=1}^{N} \rho w_{ij} \ln\left(EP_{i,t+1}/EP_{it}\right) + \beta \ln EP_{it} + \mu_i + \eta_t + \varepsilon_{it} \tag{3}$$

where ρ denotes the spatial autoregressive coefficient, u_i and η_t , respectively, denote the individual effect and the time effect, and w_{ij} represents the spatial weight matrix elements of countries i and j. In this analysis, we selected the distance function matrix as a spatial weight matrix.

The spatial error panel data model with absolute beta-convergence model is specified in Equation (4):

$$\ln\left(EP_{i,t+1}/EP_{it}\right) = \alpha + \beta \ln EP_{it} + \mu_i + \eta_t + u_{it}$$

$$u_{it} = \sum_{j=1}^{N} \lambda w_{ij} u_{it} + \varepsilon_{it} \tag{4}$$

where λ denotes the spatial error coefficient and other terms are defined in equation (3). The more description of the spatial panel data models can be found (Anselin *et al*. [33]; Elhorst, [34] [35]), therefore here we did not specify in detail. The fixed effects SAR panel data model and SEM panel data model are performed herein using MATLAB routines (adapted from Elhorst [35]). It is important to note that in the current study we divide the whole study period of 21 years into seven periods (*i.e.*, three-year time intervals: 1991-1993, 1994-1996, 1997-1999, 2000-2002, 2003-2005, 2006-2008, and 2009-2011) in order decrease the influence of business cycle fluctuations effect in this analysis as Mulder *et al*. [22].

3. Results and Discussion

3.1. Results of Sigma-Convergence

Figure 2 exhibits the sigma-convergence of energy productivity for six sectors in Asia between 1991 and 2011. The agriculture; hunting; forestry and fishing sector has slightly convergence between 1991 and 2005 and divergence since 2005. The construction sector shows a more convergence for the study period except from 1991 to 1992. The manufacturing sector displays a somewhat convergence for the period 1991-1992 and the remaining study period does not exhibit a clear pattern of convergence. The mining; manufacturing and utilities sector shows more or less similar trend to that of the manufacturing sector. The transport; storage and communications sector demonstrates a little divergence till 1995 and convergence post 1995. The wholesale; retail trade; restaurants and hotels sector shows a clear pattern of convergence during the whole study period.

In general, the sigma-convergence of sectoral energy productivity is showing somehow convergence and divergence over the study period. It can be concluded that there is a weak evidence of sigma-convergence process of energy productivity in the agriculture; hunting; forestry and fishing, manufacturing, mining; manufacturing and utilities, and transport; storage and communications sectors during the whole study period. Due to this reason, we further investigate the absolute beta-convergence including the spatial effect.

3.2. Results of Beta-Convergence

In this study, we first performed a Hausman test to select the panel data model with fixed effect and random effect before carrying out the beta-convergence analysis. **Table 2** presents the Hausman test results of energy productivity at the sectoral level. This table indicates that fixed effect model is the more appropriate than random effect model, thus, fixed effect model is applied in the present work.

Before analyzing the SAR and SEM panel data models, we used here the Moran's *I* tests on the OLS residuals. **Table 3** shows the Moran's *I* statistics results of energy productivity for each sectors. The Moran's *I* tests results show that positive spatial correlation during the study period, which implies that the spatial dependence is largely influenced by the estimated results of beta-convergence with both the SAR and SEM panel data models.

We also examined herein both SAR and SEM panel data models via Lagrange Multiplier (LM) tests (Elhorst [35]). **Table 4** displays the results of LM tests of energy productivity at the sectoral level. The results of LM tests indicate both SAR and SEM panel data models are significant for each sector. Such a result suggesting that both SAR and SEM panel data models can be further investigated in this work[2].

Table 5 summarizes the estimated results of the SAR panel data model of energy productivity convergence at

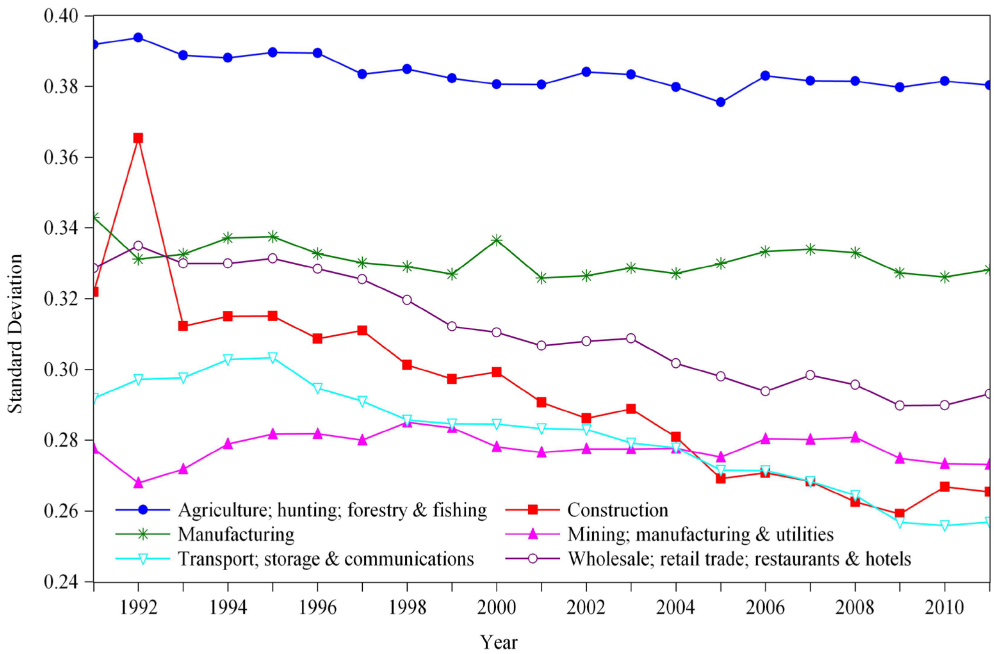

Figure 2. Sigma-convergence of energy productivity at the sectoral level for Asian countries (1991-2011). Sources: World Bank (World Development Indicators (WDI), 2013, http://data.worldbank.org/) and United Nations Statistics Division National Accounts (United Nations (UN), 2013, http://data.un.org/).

Table 2. Hausman test.

	Agriculture; hunting; forestry & fishing	Construction	Manufacturing	Mining; manufacturing & utilities	Transport; storage & communications	Wholesale; retail trade; restaurants & hotels
Hausman test	62.14	25.18	51.36	32.44	7.10	10.57
P-value	0.0000	0.0000	0.0000	0.0000	0.0546	0.0012

Sources: World Bank (World Development Indicators (WDI), 2013, http://data.worldbank.org/) and United Nations Statistics Division National Accounts (United Nations (UN), 2013, http://data.un.org/).

[2]It is important to note here we observed that the SAR panel data model and the SEM panel data model produce the similar results for each sectors. Therefore, here we only present the results of the SAR panel data model.

Table 3. Moran's *I* tests.

	Agriculture; hunting; forestry & fishing	Construction	Manufacturing	Mining; manufacturing & utilities	Transport; storage & communications	Wholesale; retail trade; restaurants & hotels
Moran *I*	0.3683	0.3874	0.4281	0.4594	0.5320	0.4956
Moran *I*-statistic	1.8397	2.0126	4.9699	7.0007	10.8971	9.1207
Probability	0.0658	0.0442	0.0000	0.0000	0.0000	0.0000

Sources: World Bank (World Development Indicators (WDI), 2013, http://data.worldbank.org/) and United Nations Statistics Division National Accounts (United Nations (UN), 2013, http://data.un.org/).

Table 4. Lagrange Multiplier tests.

	Agriculture; hunting; forestry & fishing	Construction	Manufacturing	Mining; manufacturing & utilities	Transport; storage & communications	Wholesale; retail trade; restaurants & hotels
LM lag	173.0848 (0.0000)	621.7625 (0.0000)	157.3384 (0.0000)	186.3003 (0.0000)	469.0918 (0.0000)	196.3504 (0.0000)
LM error	120.0682 (0.0000)	171.5598 (0.0000)	132.7078 (0.0000)	149.3326 (0.0000)	218.9081 (0.0000)	157.9386 (0.0000)

The p-values are in parentheses. Sources: World Bank (World Development Indicators (WDI), 2013, http://data.worldbank.org/) and United Nations Statistics Division National Accounts (United Nations (UN), 2013, http://data.un.org/).

Table 5. Estimation results of the beta-convergence using the SAR panel data model.

	Agriculture; hunting; forestry & fishing	Construction	Manufacturing	Mining; manufacturing & utilities	Transport; storage & communications	Wholesale; retail trade; restaurants & hotels
ln(EP)	−0.0011 (−0.2295)	-0.0333^{***} (−3.2958)	-0.0092^{*} (−1.2690)	-0.0091^{*} (−1.4579)	-0.0251^{***} (−3.8564)	-0.0164^{***} (−2.7156)
ρ	0.1160^{***} (5.9800)	0.0870^{***} (7.5754)	0.0920^{***} (7.0510)	0.0810^{***} (8.0278)	0.0680^{***} (10.5426)	0.0751^{***} (8.9222)
Convergence Speed (*b*)		3.79141	0.95096	0.94028	2.7603	1.74202
Half-life (*h*)		20.4667	74.995	75.8229	27.2674	41.9175
Log-like	72.0455	−46.2756	1.0647901	93.1535	66.9950	71.6348
R^2	0.0956	0.1901	0.1340	0.1751	0.3609	0.2084

The t-values are in parentheses. *, ** and ***indicate statistical significance at the 10%, 5% and 1% levels of significance. The speed of convergence (*b*) is calculated as $b = -\ln(1+T\beta)/T$, where *T* is the number of years in the period. The half-life (*h*) is defined as $h = -\ln(2)/\ln(1+\beta)$. Sources: World Bank (World Development Indicators (WDI), 2013, http://data.worldbank.org/) and United Nations Statistics Division National Accounts (United Nations (UN), 2013, http://data.un.org/)

the sectoral level across 35 Asian countries from 1991 to 2011. In the construction, manufacturing, mining; manufacturing and utilities, transport; storage and communications, and wholesale; retail trade; restaurants and hotels sectors, we found the estimated β-coefficient is negative and statistically significant. It seems that there exists an absolute beta-convergence process in energy productivity for these five sectors during the study period. However, we found no evidence of energy productivity convergence in the agriculture; hunting; forestry and fishing sector over the study period. For each sector, the estimated spatial autoregressive coefficient has positive sign and highly statistically significant. It indicates that the spatial effect has a positive impact on the energy productivity growth of adjoining countries. As can be from **Table 5**, the convergence speed with SAR panel data model are 3.79%, 0.95%, 0.94%, 2.76% and 1.74% for construction sector, manufacturing sector, mining; manufacturing and utilities sector, transport; storage and communications sector, and wholesale; retail trade; restaurants and hotels sector, respectively. The convergence speed is high for the construction (3.79%) sector, and low for the mining; manufacturing and utilities (0.94%) sector. The mining; manufacturing and utilities sector and manufacturing sector show that convergence speed is below the 1%, which implies that these two sectors convergence rate is slow. Miketa and Mulder [16] found similar result is in the manufacturing sector for 56 developed and developing countries during the period 1971-1995.

In summary, we found evidence of an absolute beta-convergence for five sectors across 35 Asian countries from 1991 to 2011 except in the agriculture; hunting; forestry and fishing sector. Such a result suggests that countries with low initial energy productivity levels tend to grow comparatively faster to catching up the high income countries. It is concluded that an absolute beta-convergence process strongly support the energy productivity growth at the five sectoral levels in Asia. The result of this analysis is in line with the finding of some recent studies (Mulder *et al.* [22]; Wan *et al.* [23]).

4. Conclusions

This paper examined the energy productivity convergence for Asian countries at the sectoral level over the period 1991-2011. The present study incorporated six main economic sectors, namely, agriculture; hunting; forestry and fishing sector, construction sector, manufacturing sector, mining; manufacturing and utilities sector, transport; storage and communications sector, and wholesale; retail trade; restaurants and hotels sector. First, we used the sigma-convergence approach to study the difference of sectoral energy productivity over time. Next, we used an absolute beta-convergence approach to investigate whether there is a convergence or divergence in the sectoral energy productivity by applying the spatial panel data models. The sigma-convergence generally indicates weak evidence of sectoral energy productivity during the whole study period except two sectors, namely, construction sector and wholesale; retail trade; restaurants and hotels sector. Moreover, our results show mixed evidence of absolute beta-convergence at the individual sectoral level in 35 Asian countries. We found strong evidence of absolute beta-convergence process in energy productivity in the construction sector, manufacturing sector, mining; manufacturing and utilities sector, transport; storage and communications sector, and wholesale; retail trade; restaurants and hotels sector, which imply a gap of sectoral energy productivity is decreasing in these Asian countries. However, there is no evidence of absolute beta-convergence process in energy productivity in the agriculture; hunting; forestry and fishing sector during our study period. This analysis also shows the convergence speed is highest for the construction (3.79%) sector and a half-life of 20 years. The spatial spillover effect is found to be strongly significant and has positive impact on energy productivity growth for each sector. Our empirical results is in favor of spatial panel data model, which implies that spatial spillover effect is significant in the process of sectoral energy productivity convergence in these 35 Asian countries.

Future study can be expanded to estimate the conditional beta-convergence process by covering the control variables such as energy price, investment, trade openness and human capital at the sectoral level of energy productivity in Asia.

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