Regional Convergence of Energy Intensity in China based on Spatial Panel Data Model
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Abstract: The evolution trends of energy intensity (EI) is relating to the implementation of national energy strategy. The empirical analysis of regional energy intensity convergence for 30 provinces from 1997 to 2011 and the influences of economic convergence, industry structure, foreign direct investment (FDI) and energy prices on the energy intensity convergence in China were conducted. Conclusions are as follows. Firstly, regional energy intensity significantly tends to converge in the process of decrease, and the convergence rate reached 14% per year. Secondly, the regions with higher energy intensity have lower per capita income, industrial structure level and FDI scale, but larger energy price rises. Thirdly, the upgrading of industrial structure and expansion of FDI can significantly enhance the declination rate of energy intensity, and then accelerate the process of energy intensity convergence between regions. Fourthly, the economic convergence process to a certain extent will enhance the declination rate of energy intensity in high energy intensity regions, but this acceleration effect for energy intensity convergence is not significant. Fifthly, rising energy prices will slow down the declination rate of energy intensity in high energy intensity region, while the deceleration effect is not obvious yet.

Keywords: energy intensity; convergence; determinants; spatial econometrics.

1. Introduction

During minimizing the differences in regional development, the efficiency and trend of energy consumption has been most crucial to the sustainable development of economy and society. It is now considered a wise choice for the undeveloped regions to implement energy conservation ra-ther than energy extension in pursuit of more developed re-gions. It is proposed that regional economic convergence, when implemented not at the cost of consuming more energy, can lead to the energy intensity convergence to some extent. But in this case, can the energy-saving economic convergence be achieved?

In recent years, the convergence of energy intensity (EI) has brought about attentions from foreign and domestic scholars. According to regional economic convergence, Markandya et al.[1] has proposed early a hypothesis for the convergence of energy intensity while was able to prove it with data from members of EU. After that, Liddile[2], Pen and Sévi[3] used different econometric methods to conduct empirical analyses with data from multiple countries, and showed continuous regional convergence of energy intensity. Other than that, Liddile[4], Meng et al.[5] also verified distinct energy intensity convergence occurred in OECD (Organization for Economic Cooperation and Development) countries. And in light of economy sectors, Mulder and de Groot[6] confirmed energy intensity convergence is faster in service industry than manufacturing industry. However, based on the study of energy intensity in some countries during 1971 to 2007, Mohammadi and Ran[7] found that the overall convergence was not significant, what’s more, conditional convergence was of better fit than absolute convergence. Addressing China’s energy intensity convergence issues, Qi et al.[8], Shi et al.[9], Qi et al.[10], Qi and Li[11] have brought forward typical discussions, with the conclusion that the convergence not only existed in per capita income difference between the east and west of China, but also in energy intensity difference. Recently, Zhao et al.[12] detected distinct regional difference within China’s energy intensity convergence, which the central and western regions showed ‘club-convergence’, and similar to the findings of Qi and Luo[8], internal convergence in the west of China was not significant.

For the factors that affect energy intensity convergence, some widespread discussions have been made, focusing on the issues of economic convergence, industrial structure upgrade, foreign direct investment (FDI) and energy price fluctuation.

Firstly, in light of economic convergence and energy intensity convergence, Zhao and Fan[13] found that the effects economy growth had on energy consumption was non-linear, asymmetric and intermittent, with two positively correlated, based on internal compliance between economy growth and energy consumption. Rühl[14] et al. analyzed the evolution patterns of both short term and long term of energy intensity in industrialization during two centuries and found that, with the specialization of composite fuel and accelerated convergence in economic sectors and technology, energy intensity would actually rise, and decreasing the dependency on any single energy source. Nevertheless, the findings of Qi and Luo[8], Qi et al.[10], Qi and Li[11] suggested the income per capita convergence and energy intensity convergence co-existed, with different rates at which they converged. Thus, there is close relationship and influence between economic convergence and energy intensity convergence.

Secondly, in light of industrial structure upgrade and energy intensity convergence, Shi[15] argued that energy den-sity would vary with different industry, and the effects of the evolution of industrial structure on energy intensity should not be ignored. This was also proven, with the study on ex-amples from Spain and Lithuania, by Mendiluce et al.[16], Baležentis et al.[17] with the findings that transportation had higher energy consumption in both countries. The findings of Mulder and de Groot[6] were even more convincing, which indicted the energy intensities in manufacturing sector and service sector are of different decreasing trends, but the structural evolution of economic sector had more and more explanatory power for the dynamics of overall energy intensity. Recently, based on the trend of Japan’s energy intensity, Okajima and Okajima[18] argued that the worsening of energy intensity had a great deal to do with the low energy efficiency of the industrial and service sectors in the 1980s. Marrero and Ramos-Reall[19] showed the transformation of energy intensity was closely related with the drop in proportion of the 2nd industry and the rise in that of the 3rd industry based on the study of EU countries. Regarding China, Fisher-Vanden et al.[20] suggested industrial structure evo-lution did have significant effects on China’s variation of energy intensity, based on the regression using data of Chi-na’s industry sector from 1997 to 1999. However, Wu[21] suggested China’s energy intensity was declining in general based on the study of regional data, which was a result of rising energy efficiency. But the transformation of the economic structure was only partly effective to the energy intensity, and leading to the conclusion that China still had huge potential for lowering energy intensity in future transformation of economic structure.

Thirdly, in light of FDI and energy intensity convergence, Shi[15] believed that, the open policy and international flow of factors correlated highly with energy intensity. Jiang and Li[22] argued that, one of the most important reason was that FDI can better investment returns, introduce advanced technology and promote human resource, bringing about direct technological and management effects, while being quite demonstrative to other enterprises. Qi et al.[10] showed the technological progress can indeed promote energy efficiency, lowering energy intensity. Thus, according to the logical relations among FDI, technological progress and energy intensity, it is concluded that FDI might indirectly reduce the energy intensity or its growth rate through technological progress, and then affect the convergence of energy intensity.

Since the reform and opening-up, China has seen huge reduction in energy intensity, and this was attributed to tech-nological progress and structural upgrade by most scholars. However, Cornellie and Frankhauser[23] proved the impacts energy price could have on energy efficiency. Their empirical research on middle and eastern European countries found that, energy price was the most crucial factor in aff
citing the energy efficiency. Fisher-Vanden et al. [20] argued that, the energy price effects could explain the reduction of 54.4% in overall energy intensity of China. Han et al. [24] and Qi et al. [10] had also confirmed the negative relationship between energy price and energy intensity. Thus, a rise in energy price can actually lower the energy intensity in a region.

In general, the literatures on energy intensity convergence showed the cross-country or cross-sectorial comparisons, and it was generally accepted that the greater energy intensity convergence existed between regions with strong economic relationship. However, regarding the study of en-ergy intensity convergence, the scholars did not seem to have paid enough attention to implicit spatial connection, or merely consider it with regional division. This somehow ignored the importance of energy intensity spatial connection which is inherently implicit in present research, and this issue exists also within the analysis of factors that affect energy intensity convergence. Due to tight connections among different regions in China, current status might not be compliant to the developing trend of energy intensity, which could indicate some convergences in the regional energy intensity of China. Thus, this article attempts to explore the methodological pathways based on present researches, internalizing spatial connections into spatial panel data models, and analyzing empirically the overall regional energy intensity convergence in China. But differing from present researches, this article emphasizes the effects on regional economic convergence, when discussing the factors affecting energy intensity.

2. The model

2.1 Model building and settings

According to the findings of Liddle[2], Ram and Mohammadi[7], the convergence of energy intensity can be expressed as follows:

\[
\ln \left( \frac{E_{i,t}}{E_{i,t-1}} \right) = a + b \ln \left( \frac{E_{i,t}}{E_{i,t-1}} \right) + u_{i,t},
\]

where \( E_{i,t} \) is expressed as the energy intensity at period \( t \) in region \( i \), reflecting the level of energy consumption per unit of output, and can be calculated through total energy consumption divided by regional GDP in the same year. \( \ln \left( \frac{E_{i,t}}{E_{i,t-1}} \right) \) is expressed as the energy intensity growth rate that period \( t \) compares with period \( t-1 \) in region \( i \). And \( a \) is a constant, \( b \) is a coefficient of energy intensity at last period, \( u_{i,t} \) is a random error.

According to Model (1), if \( b < 0 \), the energy intensity growth rate will negatively correlated to previous energy intensity level at the same region. Thus, if a region has high energy intensity, its energy intensity growth rate will be lower, vice versa. This means that energy intensity in different regions will tend to the same level.

It follows that the energy intensity can be affected by economic development, industrial structure difference, foreign direct investment and energy prices, and then the energy intensity convergence is also impacted by the regional economic convergence, industrial structure upgrading, foreign direct investment expansion and energy price fluctuation. Therefore, we give the following variables as the control variables of energy intensity convergence:

Regional economic convergence: according to Markandya[1], we use \( \ln \left( y_{i,t} / y_{i,t} \right) \), where \( y_{i,t} \) is the per-capita income in region \( i \) and \( y_{i,t-1} \) is the average per-capita income in all regions at the same period, to evaluate the level of regional economic convergence. If the regional economy tends to converge, the gap between per-capita income in region \( i \) and average per-capita income in all regions will be reduced, and thus the absolute value of \( \ln \left( y_{i,t} / y_{i,t} \right) \) will be decreased.

Industrial structure upgrade: according to Qi et al.[10], we take the proportion of third industry’s added value to regional GDP, noted as \( \ln \left( s_{i,t} \right) \), to measure the regional industrial structure. In a region, the higher proportion the third industry get, the higher the extent of third industry upgrading is, the greater the variable value of the industrial structure upgrade is.

Foreign direct investment expansion: we use \( \ln \left( FDI_{i,t} \right) \), where \( FDI_{i,t} \) is the total amount of foreign direct investment at period \( t \) in region \( i \), to express the scale of regional FDI.

Energy price fluctuation: we use \( \ln \left( p_{i,t} / p_{i,t-1} \right) \), where \( p_{i,t} \) is energy consumption price index at period \( t \) and \( p_{i,t-1} \) is energy consumption price index at period \( t-1 \), to measure the level of energy price fluctuation. If the energy consumer price index of this period is higher than the last one, the energy price fluctuation is positive, otherwise it is negative.

According to Model (1), using the above control variables, the conditional convergence model of energy intensity in China can be expressed as follows:

\[
\ln \left( \frac{E_{i,t}}{E_{i,t-1}} \right) = a + b \ln \left( \frac{E_{i,t}}{E_{i,t-1}} \right) + c \ln \left( y_{i,t} / y_{i,t} \right) + d \ln \left( s_{i,t} \right) + f \ln \left( FDI_{i,t} \right) + g \ln \left( p_{i,t} / p_{i,t-1} \right) + u_{i,t}.
\]

(2)

The energy resources are distributed in geographical space and the energy intensity has spatial association, thus it may be a better choice that using spatial econometrics to construct a model. Similar to the view of Baltagi[25], a fixed effects model may be more suitable to study energy intensity convergence of specific Chinese provinces. In a fixed effects model, main control effects include two aspects, time effect and space effect. Accordingly, we can analyze the influence of contextual variables on steady-state level in two different situations, study energy intensity convergence of specific Chinese provinces. In a fixed effects model, main control effects include two aspects, time effect and space effect. Accordingly, we can analyze the influence of contextual variables on steady-state level in two different situations, study energy intensity convergence of specific Chinese provinces.
fixed effects spatial error model(fixed effects SEM). But if is significantly equal to zero, Model (3) can be simplified to a fixed effects spatial autoregressive model(fixed effects SAR model).

For the study of regional energy intensity convergence in China, we need verify the suitability of general panel data model (2) and spatial panel data model (3) based on the spatial correlation test of OLS regression residuals. If these residuals have spatial dependence, the spatial autoregressive term or spatial error term cannot be neglected and in this case Model (3) is more suitable than Model (2), and vice versa. Main indicators about spatial correlation of panel data include Moran’s I index, LM-lag, LM-error, Robust LM-lag, Robust LM-error and so on. Moran’s I index can test directly the spatial dependence of energy intensity growth rate, and other four indicators provide the basis for the choice of specific spatial econometric panel data model. When the LM-lag and LM-error indicators are not significant, the OLS regression estimate using Model (2) is suitable. If LM-lag is significant but LM-error is not significant, a spatial autoregressive model is more suitable, and conversely if LM-lag is not significantly but LM-error is significant, a spatial error model is more appropriate. When LM-error and LM-lag indicators are significant, the choice depends on the significance of Robust LM-lag and Robust LM-error. When Robust LM-lag(or Robust LM-error) is significant, a spatial auto regressive model(or a spatial error model) is relatively better.

2.2 Data and description

In this paper, we collect empirical data from China Statistical Yearbook and China Energy Statistical Yearbook in 1998-2012. The research objects are comprised of thirty provinces in China, except for Tibet, Hong Kong, Macao and Taiwan. All regional GDP data are adjusted on the basis of the value in 1997, and then these GDP values are divided by the population at the year-end to obtain regional per capita income level under unchanged prices. For Ningxia province, total energy consumption data in 2001 is lacking and this data is filled through interpolation calculation using the average of last and next year. Similarly, for Qinghai province, FDI data of 1998 and 2000 is missing, and the same methods are used to fill these data. The energy consumption price index is measured through water, electricity and fuel constituents in regional resident’s consumer price index. And for the lack of data from 1998 to 2000, the fuel constituents in regional retail price index are used. In addition, we take 0-1 adjacent normalized matrix as spatial weight matrix, and set the weight to 1 considering that Hainan province is adjacent to Guangdong and Guangxi provinces.

3. Experimental result and analysis

3.1 Statistical description

In order to understand the evolution about energy intensity growth rate, energy intensity, per-capita income, industrial structure level, FDI and energy price fluctuation from 1998.

### Table 1. The average values of each indicator in Chinese 30 provinces.

<table>
<thead>
<tr>
<th>Year</th>
<th>energy intensity growth rate</th>
<th>energy intensity</th>
<th>per-capita income</th>
<th>industrial structure level</th>
<th>FDI scale</th>
<th>energy price fluctuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>-0.2253</td>
<td>2.0484</td>
<td>0.7347</td>
<td>0.3598</td>
<td>16.3167</td>
<td>-2.5367</td>
</tr>
<tr>
<td>1999</td>
<td>-5.7451</td>
<td>1.9471</td>
<td>0.7942</td>
<td>0.3746</td>
<td>14.8251</td>
<td>0.2267</td>
</tr>
<tr>
<td>2000</td>
<td>-2.6443</td>
<td>1.8897</td>
<td>0.8436</td>
<td>0.3817</td>
<td>15.1040</td>
<td>16.7767</td>
</tr>
<tr>
<td>2001</td>
<td>-5.4466</td>
<td>1.8075</td>
<td>0.9167</td>
<td>0.3925</td>
<td>17.0592</td>
<td>3.5575</td>
</tr>
<tr>
<td>2002</td>
<td>1.4144</td>
<td>1.8112</td>
<td>1.0070</td>
<td>0.3947</td>
<td>20.0970</td>
<td>4.0167</td>
</tr>
<tr>
<td>2003</td>
<td>2.0537</td>
<td>1.8784</td>
<td>1.1184</td>
<td>0.3861</td>
<td>23.2319</td>
<td>5.9629</td>
</tr>
<tr>
<td>2004</td>
<td>1.8815</td>
<td>1.9134</td>
<td>1.2533</td>
<td>0.3697</td>
<td>24.0685</td>
<td>7.3158</td>
</tr>
<tr>
<td>2005</td>
<td>0.2550</td>
<td>1.9843</td>
<td>1.4084</td>
<td>0.3992</td>
<td>26.5040</td>
<td>8.6755</td>
</tr>
<tr>
<td>2006</td>
<td>-2.5254</td>
<td>1.8674</td>
<td>1.5729</td>
<td>0.3947</td>
<td>35.0891</td>
<td>5.8921</td>
</tr>
<tr>
<td>2007</td>
<td>-4.1845</td>
<td>1.7920</td>
<td>1.7784</td>
<td>0.3931</td>
<td>43.2860</td>
<td>3.4419</td>
</tr>
<tr>
<td>2008</td>
<td>-5.4896</td>
<td>1.6929</td>
<td>1.9669</td>
<td>0.3841</td>
<td>50.3311</td>
<td>7.1301</td>
</tr>
<tr>
<td>2009</td>
<td>-5.3717</td>
<td>1.6023</td>
<td>2.1706</td>
<td>0.4116</td>
<td>53.2632</td>
<td>-0.3778</td>
</tr>
<tr>
<td>2010</td>
<td>-8.5413</td>
<td>1.5128</td>
<td>2.4136</td>
<td>0.3997</td>
<td>62.3106</td>
<td>5.7117</td>
</tr>
<tr>
<td>2011</td>
<td>2.1861</td>
<td>1.5199</td>
<td>2.6800</td>
<td>0.3978</td>
<td>75.9354</td>
<td>3.4556</td>
</tr>
</tbody>
</table>

Note: The units of indicator are respectively set to: energy intensity, 10 thousand tons of standard coal per 100 million yuan; per-capita income, 10 thousand yuan per person; FDI scale, 100 million dollars; energy intensity growth rate and energy price fluctuation, %. And per-capita incomes calculated on basis of the unchanged prices in 1997, and the levels of regional energy price fluctuation are based on the data of last year. In 2011, we calculate respectively the average of 30 provinces’ indicators in different years and show results in Table 1.

From Table 1, it can be seen that most regional energy intensity growth rate is negative, and even the average de-clines is more than 8% in 1999 and 2000. With overall negative growth of energy intensity, the energy intensity is re-duced from about 20000 tons of standard coal per 100 mil-lion yuan in 1998 to about 15000 in 2011(as shown using black thick lines in Figure 1). On the whole, the average of energy consumption per unit of output decrease about 25% in all regions. This shows that in China, the efficiency of energy utilization has been increased and the quality of eco-nomic development has been improved on the process of economic growth in recent years.

In Figure 1, it can be shown that in some provinces, pre-vious energy intensities are relatively higher but the intensity has fell down in recent years. In 1997, for 70% of provinces, the energy intensities are between 0.5 and 2.5, but in 2011, for 77% of provinces, the energy intensities are between 0.5 and 2.0, and the number of provinces with higher energy intensity than the average decreased from 12 in 1997 to 9 in 2011. Even more, the evolutions of energy intensity shows that the drop degree is relatively limited in the provinces which previous energy intensity is relatively low, and vice versa. This means that the growth rate (specifically decrease rate) of energy intensity is negatively related to initial value of energy intensity, and the convergence of the regional energy intensity is very obvious.
In light of per-capita income index, the average of regional per-capita income on the basis of unchanged price in 1997 maintains a certain rate of growth. The average of regional per-capita income rose from 7347 yuan in 1997 to 26800 yuan in 2011, and total growth rate is 265% and the average growth rate is 9.68% (as shown by black thick lines in Figure 2). The evolutions of the per-capita income under unchanged price from 1997 to 2011 for 30 provinces are shown in Figure 2, and the per-capita income of each province has kept a similar exponential growth trend. There are two representative curves. The topmost curve represents Shanghai, and the per-capita income increases from 23062 yuan in 1997 to 61470 yuan in 2011, total growth rate is 166.54%, the average growth rate is 7.25%. The downmost curve represents Guizhou, and the per-capita income increases from 2199 yuan in 1997 to 9775 yuan in 2011, total growth rate is 344.52%, the average growth rate is 11.24%. As seeing from these two typical curves, the annual growth rate is faster of the province having a low initial per-capita income than the province having a high initial per-capita income. As the majority existing studies have proved, the regional per capita income has a certain convergence. Compared Figure 2 with Figure 1, we can find that the convergence of regional energy intensity tends to a lower level, but the convergence of regional per-capita income tends to a higher level, and the convergence speed of energy intensity is faster than the per-capita income.

From the industrial structure level measured by the proportion of third industrial added value and GDP, we can find that the average level of industrial structure is gradually raised from 1998 to 2002, but the level has a fluctuating trend from 2002 to 2011. For the FDI index, the average scale of foreign direct investment has a trend of expansion. Specifically, FDI has increased from 1631.67 million dollars in 1998 to 7393.54 million dollars in 2011, the total growth rate is 351.13%, and the average growth rate is 12.33%. However, the energy price underwent a great fluctuation. For example, the energy price indexes have declined in 1998 and 2009 but have rose in other years compared to the previous year, and specially the growth rate of regional energy price is more than 16% in 2000.

3.2 Optimal model

Due to the spatial correlation of energy intensity and the necessity of controlling the fixed effect, the methods of OLS and spatial correlation test are used in this part. Based on the panel data, Model (2) is estimated respectively through the mixed effects panel data model, the regional fixed effects panel data model and the bidirectional fixed effects panel data model. The results are shown as Table 2.

According to Table 2, the statistical test results of the mixed effects, regional fixed effects and bidirectional fixed effects panel data models show that the fixed effects panel data model is the best model. The adjusted goodness-of-fit of mixed effects panel data model is only 0.57%, and it is far less than 8.20% of regional fixed effects panel data model and 6.90% of bidirectional fixed effects panel data model. And the log likelihood function value LogL of regional fixed effects panel data model and bidirectional fixed effects panel data model are higher than the ratio of mixed effects panel data model. In light of these two indica-tors, it is more fitting to study the energy intensity convergence using regional fixed effects panel data model and bidirectional fixed effects panel data model than using mixed effects panel data model. Furthermore, the comparative results of statistical index show that the log likelihood function value of bidirectional fixed effects panel data model is slightly higher than regional fixed effects panel data model, but the goodness-of-fit of regional fixed effects panel data model is 1.3% higher than the one of bidirectional fixed effects panel data model. Overall, similar to Baltagi[25], we need control the fixed effects, and it means that the regional fixed effects panel data model is more fitting.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mixed effects panel data model</th>
<th>Regional fixed effects data panel data model</th>
<th>Bidirectional fixed effects panel data model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.6101 (1.1673)</td>
<td>-0.1350*** (-6.2513)</td>
<td>-0.1301*** (-5.674)</td>
</tr>
<tr>
<td>ln(E_{i,t})</td>
<td>-0.0179*** (-2.2176)</td>
<td>-0.0862 (-0.9803)</td>
<td>-0.0639 (-0.7523)</td>
</tr>
<tr>
<td>ln(y_{i,t}/y_{i,t}^{*})</td>
<td>-0.0034 (-1.807)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The energy intensity has not spatial autocorrelation, and the original hypothesis of Robust LM-error is that the growth rate of the energy intensity panel data model, only Robust LM-lag is significant at 10% level. The original hypothesis of Robust LM-lag is that the growth rate of energy intensity do not exist the spatial error correlation. This means that it is necessary to control the regional effects about the energy intensity and pay attention to the spatial correlation about the growth rate of regional energy intensity. Therefore, considering the space effects, the spatial autoregressive model (the SAR model, also called by spatial lag model) in the spatial econometrics model (3) is better choice for the study of energy intensity convergence.

3.3 The analysis of energy intensity convergence

The time interval of this study is one year, so it can be estimated that \( \delta = 0.1419 \) by \( \delta = \frac{\log(1.1419)}{1} \). At present, most studies of economic convergence shows that the energy intensity convergence has significant spatial correlation and neglected spatial dependence. The spatial correlation statistical test results of regional fixed effect panel data model fitting for this study show that Moran’s I index, LM-lag and LM-error are all significant and the spatial correlation also cannot be ignored. Furthermore, for Robust LM-lag and Robust LM-error of regional fixed effects panel data model, only Robust LM-lag is significant at 10% level. The original hypothesis of Robust LM-lag is that the growth rate of the energy intensity has not spatial autocorrelation, and the original hypothesis of Robust LM-error is that the growth rate of the energy intensity do not exist the spatial error correlation. This means that it is necessary to control the regional effects about the energy intensity convergence and pay attention to the spatial correlation about the growth rate of regional energy intensity. Therefore, considering the space effects, the spatial autoregressive model (the SAR model, also called by spatial lag model) in the spatial econometrics model (3) is better than the general panel data model (2) in the study of the energy intensity convergence. On the whole, the regional fixed effects SAR model is best choice for the study of energy intensity convergence.

<table>
<thead>
<tr>
<th>Variable</th>
<th>regional fixed effects SAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \rho )</td>
<td>0.1110* (1.7018)</td>
</tr>
<tr>
<td>( \delta )</td>
<td>-0.3156 (-0.0757)</td>
</tr>
<tr>
<td>( \ln(\text{EI}_{it}) )</td>
<td>-0.1323*** (-6.1962)</td>
</tr>
<tr>
<td>( \ln(\text{EI}_{it}) )</td>
<td>-0.0846 (-0.9732)</td>
</tr>
<tr>
<td>( \ln(\text{EI}_{it}) )</td>
<td>-0.1681** (-1.9833)</td>
</tr>
<tr>
<td>( \ln(FDI_{it}) )</td>
<td>-0.0712** (-2.3654)</td>
</tr>
<tr>
<td>( \ln(\text{FDI}_{it}) )</td>
<td>0.0872 (0.8143)</td>
</tr>
<tr>
<td>( \rho^2 )</td>
<td>0.1212</td>
</tr>
<tr>
<td>corr - ( \rho^2 )</td>
<td>0.0925</td>
</tr>
<tr>
<td>LogL</td>
<td>325.1440</td>
</tr>
</tbody>
</table>

Note: In Table 3, the values in bracket is statistical values; ***, **, and * respectively represent 1%, 5% and 10% significant level.

For the spatial correlation of regional fixed effects SAR model, the spatial autocorrelation coefficient is 0.1110 and is significant at 10% level, which indicate that the growth rate of energy intensity has a significant positive spa-tial correlation. This implies that the growth rate of energy intensity in adjacent regions can bring the synclastic effects for the growth rate of energy intensity in local region. That is, the decline of energy intensity in adjacent regions also can lead to the decline of energy intensity in local region. There-bre, the growth rate of energy intensity has a very significant regional assimilation.

For the fixed effects control of regional fixed effects SAR model, the regional fixed effects coefficient is -0.3156, which shows that on the whole, every region has its own characteristics, and the growth rate of energy intensity in some regions even exit certain initial disadvantages. However, this coefficient cannot be tested by the significance in 10% level, and thus the regional fixed effects is not obvious, the initial disadvantage does not impact strongly on the growth rate of energy intensity.

For the coefficient estimation of initial energy intensity, the coefficient of Model (3) is -0.1323 and is significant at 1% level. It means that it is a negative correlation between the initial energy intensity and the growth rate of energy intensity, and the results are the same to Fig. (1), the energy intensities of 30 provinces in China have a good convergence between 1997 and 2011. When the initial energy intensity increase 1%, the growth rate of energy in-tensity will decrease 0.13%. According to actual situation of China from 1997 to 2011, the energy intensity of most re-gions has shown a declining trend, that is, the growth rate of energy intensity is negative. Therefore, for the region having higher initial energy intensity, at first the declining speed of energy intensity is fast. But with the gradual decrease of the absolute level of energy intensity, this declining speed would slow down. On the contrary, for the region having lower initial energy intensity, at first the declining speed of energy intensity is slow, and would be slower with the decrease of the absolute level. In this case, the energy intensity of all regions will tend to converge. According to Markandya et al.[1], is denoted as \( \delta \), where represent the speed of convergence. The time interval of this study is one year, so it can be estimated that \( \delta = 0.1419 \) by . At present, most studies of economic convergence
showed that the speed of regional economic convergence is about 2%, but a few studies suggested that the speed is faster than 2%. It follows that the energy intensity in China not only has a significant convergence, but also converges at a speed of 14.19% per year, and this convergence rate is significantly faster than others.

For the indicator of regional economic convergence, its coefficient is -0.0846 and not significant. This indicates that the process of economic convergence has a weak but inapparent influence on the convergence of regional energy intensity. Specifically, when the per-capita income of one region is lower than the average of all regions, the economic convergence can lead to a result that the growth rate of per-capita income in this region is faster than the growth rate of all regions’ average in the next period. The estimated results showed that when the gap of per-capita income between this region and all regions decrease 1%, the extra growth rate of regional energy intensity will increase about 0.08% in this region. For each region, if the speed of convergence to the average value is 2% per year, the extra growth rate of regional energy intensity will be 0.16%. It is assumed that the per-capita income of region is less than the one of region which is close to the average level, and then if the economic level of region has converged to the approximate level of region, the effects of regional economic convergence on the growth rate of energy intensity will be disappeared. The correlation tests between the initial energy intensity and the regional economic convergence of 30 prov-inces in 1998-2011 indicate that the correlation coefficient is -0.5062 and the statistical value is -12.0016, that is, the correlation is significant at 1% level. This shows that the higher the regional initial energy intensity is, the smaller the regional economic convergence index is, and the greater the gap between per-capita income of this region and the average of per-capita income. Thus, when the economic convergence of one region when having low per-capita income to the average level, the index of the economic convergence will be raised, and the growth rate of energy intensity will be decreased accordingly. The negative correlation between energy intensity and regional economic convergence also shows that the region with a lower per-capita income has a higher energy intensity. Therefore, the convergence of regional economy can slow down the growth rate of energy intensity, and even lead to a negative growth of energy intensity. That is to say, the process of economic convergence promotes the convergence of energy intensity.

For the indicator of regional industrial structure level, its coefficient is -0.1681 and it is significant at 5% level. Thus, if the economic structure level measured by the ratio of added value of third industry and the total output increase 1%, the growth rate of its energy intensity will de-increase 0.16%. This shows that if the faster development of third industry is achieved, this industry will be able to play out its advantages for energy consumption and promote the further decline of energy intensity. In particular, the average level of regional economic structure has rose from 35.98% in 1998 to 39.78% in 2011, the added value is 3.8%, the growth ratio is 10.56%, and the growth ratio of per year is 0.78%. With the 0.78% growth of industrial structure per year, the overall growth rate of energy intensity will reduce about 0.12%. On the other hand, the correlation tests between initial level of energy intensity and the level of economic structure at 30 provinces in 1998-2011 indicate that the correlation coefficient of two indexes is -0.1894, and the statistical value is -3.9427, the correlation is significant at the 1% level. This means that the economic structure of one region with a high energy intensity is relatively low. Therefore, for the region with high energy intensity, the way of upgrading industrial structure is reducing the declining speed of energy intensity and then promoting the decline of absolute energy intensity level and the achievement of regional convergence.

For the indicator of foreign direct investment scale, its coefficient is -0.0172 and it is significant at 5% level. Similar to the upgrade of regional economic structure, the FDI scale of one region rise 1%, and the growth rate of its energy intensity will decrease 0.01%. FDI can effectively reduce the regional energy intensity indirectly through technical effects and management effects. Between 1998 and 2011, the FDI scale has rose 12.33% per year and thus the average declining rate of the energy growth rate is 0.12% per year. The correlation tests between the initial energy intensity level and the foreign direct investment scale at 30 provinces in 1998-2011 indicate that the correlation coefficient of two indexes is -0.6956, and the statistical value is -19.7929, the correlation is significant at the 1% level. This means that the regional energy intensity has a relatively low FDI scale. Therefore, for the region with high energy intensity, the growth of FDI scale can push rapidly the declining speed of energy intensity, and thus promote the decrease of absolute energy intensity level and the convergence of regional energy intensity.

In light of the indicator of regional energy consumption price fluctuation, its coefficient is 0.0872. This shows that the energy price fluctuation increases 1%, the growth rate of its energy intensity will rise 0.08%, but this same direction growth between price fluctuation and energy growth is not obvious. In general, the energy price fluctuation of every year has different range and even different direction in each region, and this leads to different fluctuation range of regional average energy price index. The energy price index undergo an increase in most years but a decrease in a few year. In the findings of most existing researches, there is a negative correlation between the level of energy price and the level of energy intensity, that is, the higher the level of energy prices is, the lower the energy intensity will be. However, the positive value of statistical coefficient shows that the upward fluctuation of energy prices do not play a role in reducing growth rate of energy intensity. The study of this paper shows that the growth of energy prices has even bring an weak and insignificant growth of energy intensity. On the whole, the current energy price mechanism do not play a substantial role in the decline of energy intensitiy. This negative correlation between energy prices and energy intensity may be only a superficial reflection between the growth of overall energy prices and the decline of overall energy intensity. It is unrealistic to explain that the growth of the energy price will bring the decline of energy intensity. Probably the decline of energy intensity is attributed to some other key factors. At present, the overall growth rate of energy intensity is negative, and the energy price increases along with positive growing energy intensity. Therefore, the energy price mechanism has not played the role of promoting the decline of energy intensity, but has played a certain role in slowing down the energy intensity. Furthermore, the correlation tests between the initial level of energy intensity and the index of energy price fluctuation at 30 provinces from 1998 to 2011 indicate that the correlation coefficient is 0.0949, the statistical value is 1.9488, and the correlation is significant at the 10% level. This shows that the growth of energy price is more obvious in the region with high energy intensity currently. Therefore, under the same conditions, with the rise of energy prices, the declining speed of energy intensity in one region with high original energy intensity become slower. That is, current energy price mechanism slows down the speed of energy intensity convergence.

4. Conclusion

In general, the energy intensity convergence should coex-is-t with economic convergence, and this can be very im-port-ant to sustainable development of the economy and society. In minimizing the regional difference in developing the economy, the industry structure upgrade and FDI implementa-tion should be stressed in under-developed regions with higher energy intensity. In this way, we can expose the po-tential for lowering the energy intensity, promote a complete energy price mechanism, lower the energy intensity in pro-moting regional economy and minimizing regional differ-ence, enhance the cooperation between regional economy and energy intensity as in the convergence, and ultimately solve the energy and resource conflicts hindering the devel-opment of economy and society.

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