Decomposition Study of Factors for Energy Intensity Change in Shaanxi Province Based on LMDI Method

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Abstract. The in-depth study of the reasons for regional energy intensity change not only contributes to the scientific formulation of policies related to regional energy conservation and emission reduction, but also constitutes great significance for energy security and climate change countermeasures. Based on the LMDI decomposition method, this paper gives a quantitative analysis of the influence of three factors, namely, production effect, energy structure effect and energy intensity, on the energy intensity of Shaanxi Province. Results demonstrate that the production effect, in other words, the economic growth greatly enhances energy consumption. Structure effect and energy intensity effect shows that the adjustment of industrial structure and the improvement of energy efficiency jointly lead to the reduction of energy intensity. As a result, to improve energy efficiency in the future, Shaanxi Province should regard optimizing the industrial structure as a long-term strategy and complete the transformation and upgrading of its industrial structure.

1. Introduction

Energy intensity is the ratio of energy utilization to the economic or material output. At the national level, energy intensity is the total usage of domestic energy or the ratio of the final energy usage to gross domestic product.[1] Energy intensity is one of the most common indicators to compare the comprehensive energy utilization efficiency in different countries and regions, which reflects the economic benefits of energy utilization. [2]There are two most commonly used methods to calculate energy intensity: one is the energy consumed by the per unit of gross domestic product (GDP), and the other is the energy consumed by per unit of output.

In the study of energy intensity, researchers at home and abroad usually decompose the change of energy intensity trend into many variable and invariable factors.[3] Through the study of these factors and the influence of these factors on the intensity of energy intensity, common methods to analyze the reasons of energy intensity change are: (1) Laspeyres index algorithm, which traces the influence of particular factor change on energy intensity from the perspective of final values of all factors. The basis of the Laspeyres index algorithm is to divide the ratio of energy intensity into the product of the structure effect and the intensity effect, according to the change in the proportion of each industrial sector to the total industrial output. (2) Arithmetic Mean Divisia Index (AMDI) can decompose the variables of energy intensity, dividing variables of energy group intensity into structure effect and energy intensity effect by methods of addition and multiplication. (3) The innovation of Logarithmic

Mean Divisia Index (LMDI) is the replacement of arithmetic mean value by logarithmic mean value to remove the residual.

Divisia algorithm can be divided into categorized into Arithmetic Mean Divisia Index (AMDI) and Logarithmic Mean Divisia Index (LMDI). The Laspeyres index method and the AMDI method have residual that cannot be decomposed, while the LMDI method can eliminate residual. [4]This is the reason why LMDI method is considered a better factor decomposition method at present and widely used in analyzing the reasons for the change of the index. [5]After examining and weighing of various methods, this paper intends to adopt LMDI decomposition method to decompose the cause of energy intensity change since the LMDI decomposition method has the following features: the result from multiplication and addition can be converted to each other; the result of the multiplicative decomposition also has the addition characteristic; the sum of the effect of divisions or the industries decomposition is exactly the same as the total effect; the decomposition results can avoid redundant and undivided residual.

2. Decomposition Method

If the logarithmic mean rather than the arithmetic mean is used to eliminate residual, the logarithmic mean of positive numbers x and y should be:

$$L(x,y) = \frac{(y-x)}{\ln(y/x)} \tag{3.1}$$

When the logarithmic mean is used to replace the arithmetic mean, the multiplicative decomposition of the structure effect and energy intensity should be:

$$D_{Str} = \exp\left\{\sum_i \frac{L(w_{i,T}, w_{i,0})}{\sum_i L(w_{i,T}, w_{i,0})} Ln(S_{i,T}/S_{i,0})\right\} \tag{3.2}$$

$$D_{int} = \exp\left\{\sum_i \frac{L(w_{i,T}, w_{i,0})}{\sum_i L(w_{i,T}, w_{i,0})} Ln(I_{i,T}/I_{i,0})\right\} \tag{3.3}$$

While the additive decomposition of the structure effect and energy intensity should be:

$$\Delta I_{Str} = \sum_i L\left(\frac{E_{i,T}}{Y_T}, \frac{E_{i,o}}{Y_0}\right) Ln\left(\frac{S_{i,T}}{S_{i,0}}\right) \tag{3.4}$$

$$\Delta I_{int} = \sum_i L\left(\frac{E_{i,T}}{Y_T}, \frac{E_{i,0}}{Y_0}\right) Ln\left(\frac{I_{i,T}}{I_{i,0}}\right) \tag{3.5}$$

D_{act}, D_{stur}, D_I represent production effect, energy structure effect and energy intensity respectively, and D_{tot} represent the total energy consumption effect.

3. Data Source and Interpretation

The data of energy consumption and energy intensity used in this paper is derived from the total energy consumption in different industries (Unit: 10,000 tons of standard coal) in the Shaanxi Statistical Yearbook. This paper decomposes energy consumption and energy intensity variables of 29 sectors in the second industry (the agricultural food processing industry, food industry, beverage manufacturing, tobacco products industry, textile industry, textile and clothing shoes and hats, leather fur feathers (fine hair) and its products, wood processing and wood, bamboo rattan palm grass

products industry, furniture, paper and paper products, printing and record the replication of media, culture and education sporting goods manufacturing industry, oil processing and coking and nuclear fuel processing industry, chemical raw materials and chemical products manufacturing, pharmaceutical manufacturing, chemical fiber industry, non-metallic mineral products, rubber products, plastic products, Black metal smelting and rolling processing industry, non-ferrous metal smelting and rolling processing industry, fabricated metal products, general equipment manufacturing industry, special equipment manufacturing, transportation equipment manufacturing, electric machinery and equipment manufacturing, communications equipment computer and other electronic equipment manufacturing, instrumentation and cultural office machinery manufacturing, handicrafts and other manufacturing, handicrafts and other manufacturing industries) in Shaanxi Province from 1994 to 2013. It needs to be explained that before 2009, the listed plastic products and rubber products in the manufacturing industry are separated; however, after 2009, they merged. In addition, the statistics of car manufacturing industry are not available until 2009. In the 2005 Statistical Yearbook, energy statistics of 2004 is not included. Therefore, in the decomposition, this paper directly decomposes figures from 2003 to 2005.

4. Analysis of Decomposition Results

The results of the product decomposition of energy intensity of Shaanxi Province are shown in table 3-1. From table 3-1 and table 3-2, it can be seen that although the overall energy consumption has lowered from 1996 to 1997 and 1998 to 1999, energy consumption in general maintains a growing trend, with the typical increase of 1012.27 from 2010 to 2011. It can be seen that the change of energy intensity is mainly under the influence of energy production and structure effect, with figures from 2002 to 2006 showing this influence more obviously.

Table 3-1. Product Decomposition of Energy Consumption in Shaanxi from 1994-2013.

year	D_{tot}	D_{act}	D_{stur}	D_I	year	D_{tot}	D_{act}	D_{stur}	D_I
1994-1995	1.231	1.1247	0.9724	1.1343	2003-2005	1.005	0.4108	4.0029	9.4232
1995-1996	1.733	1.4428	1.1615	1.0368	2005-2006	1.167	1.1950	1.0121	0.0625
1996-1997	0.970	0.9231	0.9174	1.1425	2006-2007	1.036	1.1933	0.9462	2.5712
1997-1998	1.006	0.9642	0.8637	1.2112	2007-2008	1.074	1.1771	0.9966	0.4716
1998-1999	0.656	1.0627	1.0085	0.6121	2008-2009	1.064	1.1351	0.9355	0.6944
1999-2000	1.564	0.9568	1.0706	1.3211	2009-2010	1.083	1.3258	0.9983	0.8184
2000-2001	1.162	1.2498	1.0379	0.9003	2010-2011	1.105	1.2771	1.0440	0.8282
2001-2002	1.121	1.1472	0.9845	0.9985	2011-2012	1.122	1.1463	1.1542	0.8483
2002-2003	1.015	9.5133	0.1451	0.7400	2012-2013	1.079	1.1290	1.0192	0.9363

The result of addition decomposition of energy intensity in Shaanxi is displayed in table 3-2. It can be perceived from table 3-2 that although the methods of product decomposition and addition

decomposition of energy intensity are slightly different, the results are consistent. Results show that the production effect is 2402.21 in the 19 years from 1994 to 2013, indicating that economic growth contributes greatly energy consumption. The structure effect and energy intensity are 10399.84, -9802.94 respectively, showing that the adjustment of industrial structure and the improvement of energy efficiency jointly result in the reduction of energy intensity.

Table3-2. Addition Decomposition of Energy Consumption in Shaanxi from 1994-2013.

year	ΔE_{tot}	ΔE_{act}	ΔE_{stur}	ΔE_I	year	ΔE_{tot}	ΔE_{act}	ΔE_{stur}	ΔE_I
1994-1995	174.95	97.46	-23.20	104.52	2003-2005	10.01	-8784.81	13695.71	22149.74
1995-1996	683.04	451.25	184.28	44.47	2005-2006	312.47	1844.70	124.43	-28711.14
1996-1997	-48.57	-126.03	-135.88	209.94	2006-2007	78.89	689.53	-215.86	3685.37
1997-1998	9.5	-56.83	-228.05	298.25	2007-2008	168.04	780.65	-16.54	-3599.09
1998-1999	-541.87	77.59	10.75	-626.25	2008-2009	155.51	383.26	-201.73	-1103.23
1999-2000	375.8	-52.88	81.71	333.44	2009-2010	215	759.71	-4.71	-540.02
2000-2001	227.94	334.72	55.81	-157.65	2010-2011	1012.27	720.67	126.93	-555.31
2001-2002	198.08	236.55	-26.92	-2.59	2011-2012	378.99	447.91	470.39	-539.90
2002-2003	26.98	4161.22	-3565.87	-556.15	2012-2013	273.64	437.54	68.59	-237.34

According to Figure 3-1, energy intensity in Shaanxi Province displays an overall downward trend, but there is a small rebound from 2000 to 2002. The decline rate after 2003 falls compared with that before 2000, with descent rate of energy intensity rather slow. From the decomposition results of Figure 3-1, it can be perceived that the rebound is caused by both the adjustment of industrial structure and the improvement of energy efficiency. The inseparable relationship of these two factors manifests itself when theoretical data to socioeconomic status are linked.

5. Major Conclusion and Policy Recommendations
Carrying with the purpose of energy conservation, this paper, based on the LMDI model, decomposes energy consumption and variables of energy intensity of 29 sectors of the second industry in Shaanxi Province, and the results of the study are of practical policy significance. Results of this study show that:

First, the energy intensity of Shaanxi Province in general presents a declining state, which has a positive influence on promoting green economic growth in Shaanxi.

Second, the production effect, namely, economic growth becomes an engine for huge increase of energy consumption. The overall change of economic growth has a positive effect on energy intensity in Shaanxi Province, but the influence of economic growth on energy intensity is lower than that of structure effect and energy intensity effect;

Third, the adjustment of industrial structure and the improvement of energy efficiency jointly lead to the reduction of energy intensity. The positive influence of structure effect outweighs the side reaction of energy intensity effect, eventually resulting in the decrease of energy intensity. [6]This would help facilitate Shaanxi's purpose of green economic growth and industrial structure upgrading.

According to the results of the analysis and other related research, in order to lower energy intensity and realize energy conservation in Shaanxi Province at present and in the future, the major task is to reduced, and the main task is to restrain excessive growth of the discharges caused by the irrational economic growth pattern. This paper puts forward the following suggestions:

(1) In the field of industrial development, the starting point should be conducting energy conservation in industrial development, balancing industrial structure, rationalizing industrial layout, and promoting continuous policies on structural adjustment, with the focus of establishing and developing industrial structure of low energy consumption. [7]

(2) In terms of energy consumption, each region in Shaanxi Province should make use of technological innovation and strengthen policy guidance to enrich the means of restricting emissions growth, achieving a combining effect of energy efficiency and structure improvement; in addition, the joint intensity of energy efficiency effect and structural improvement effect should be vigorously promoted, forming a double control over the irrational economic growth.

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