

Analysis on energy consumption in Shandong Province: Based on C-D Model

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Abstract

This paper analyzes the energy consumption of Shandong Province by the use of Complete Decomposition Model. We decompose three key factors: economic growth, structure and energy intensity, and study the impact on energy consumption results brought by changes in these variables. The corresponding effect coefficients is compared with national average level to identify the characteristics of energy consumption changes in Shandong and specific effects of every stage of each factor, providing a scientific basis for the development of energy policy making.

Keywords: energy consumption, Complete Decomposition Model, economic growth, energy intensity

1. Introduction

In recent years, China's rapid economic development has stimulated the fast growth of energy consumption, resulting in the increasingly prominent imbalances of energy supply and demand (Cai Jiu-ju, 2006). The relationship between energy consumption and economic development has become the focus of attention. The specific impact on energy consumption growth is the key in analyzing energy consumption. Abroad studies in this field have mainly focused on two aspects: first, exploiting the concept of energy intensity to quantitative the relationship (Jenne, 1983). Second, the contribution and driving role that the energy sectors of national economy make on energy consumption are studied (Bending, 1987). These studies could not give the economic factors affecting energy consumption and its effects, but they provide ample theoretical and empirical basis (Raggi, 1992).

Shandong is one of China's large economies and populous provinces, since 2002, GDP of this province ranked the third in the country, accounting for about one-tenth of national total GDP, and population ranked the second. Meanwhile, the economic structure and economic development pattern of Shandong Province has a similarity to the nation. Therefore, it is significant to study the relationship between economic development and changes in energy consumption in Shandong Province and to identify changes in factors affecting energy consumption and its impacts. On the base of elaborating the situation of Shandong Province's energy consumption and economic development, this literature exploits complete decomposition model to calculate the influencing factors as GDP effect coefficient (Ge), energy intensity coefficient (Ie) and economic structure coefficient (Se). A quantitative analysis is used, compared with the national average level, we sum up the factors characteristics that affect energy consumption in Shandong Province and provide energy policy references.

2. Empirical Framework

Since Stanford University Professor Paul R. Ehrlich generated decomposition model in 1971 (Tao Zai-pu, 2003), Hankinson et al had used this model to study electricity and other energy issues (Hankinson, 1983), and Boyd and Howarth have exploited decomposition method in studying the factors that influence energy consumption changes in different countries, disaggregating two factors as economic structure and energy intensity effects (Boyd, 1988). All of these studies not only popularized the employments of decomposition method but also provided many references for energy management and making policies (Howarth, 1991). However due to residual problems in decomposition, the accuracy of the results should to be improved. On the base of decomposition model, Sun presented a complete decomposition model that eliminated the residual impact of the decomposition process, making the result of factor decomposition more accurate (Sun, 1998).

This paper will use complete decomposition model to explain changes of energy consumption in three driving aspects: economic growth, economic structure and technological level, and that is the GDP (G_e), economic structure and the effect of energy intensity (S_e and I_e). Their effecting coefficient and the proportion will reflect the corresponding degree of influence in energy consumption change. The unit of analysis is by energy consumption in each industry E_i , GDP created by each industry G_i , energy intensity I_i , and the proportion of each industry's GDP to the total GDP S_i , of which i said that agriculture, industry and other industries. Our decomposition model is:

$$E = G \times \frac{E}{G} = G \times \frac{\sum E_i}{G} = G \times \frac{\sum I_i G_i}{G} = G \times \sum I_i S_i, \quad (1)$$

$$\Delta E = E^t - E^0 = G^t \times \sum I_i^t S_i^t - G^0 \times \sum I_i^0 S_i^0 \quad (2)$$

Where, t is difference between current year and initial year. The complete decomposition model is presented in equation (3), (4), (5), (6).

$$G_e^t = \Delta G \sum_i I_i^0 S_i^0 + \frac{1}{2} \Delta G \sum_i (I_i^0 \Delta S_i + S_i^0 \Delta I_i) + \frac{1}{3} \Delta G \sum_i \Delta I_i \Delta S_i; \quad (3)$$

$$I_e^t = G^0 \sum_i S_i^0 \Delta I_i + \frac{1}{2} \sum_i \Delta I_i (S_i^0 \Delta G + G^0 \Delta S_i) + \frac{1}{3} \Delta G \sum_i \Delta I_i \Delta S_i; \quad (4)$$

$$S_e^t = G^0 \sum_i I_i^0 \Delta S_i + \frac{1}{2} \sum_i \Delta S_i (I_i^0 \Delta G + G^0 \Delta I_i) + \frac{1}{3} \Delta G \sum_i \Delta I_i \Delta S_i; \quad (5)$$

$$\Delta E = G_e^t + I_e^t + S_e^t. \quad (6)$$

3. Description of Energy Consumption in Shandong Province

GDP growth has played a driving role in energy consumption. With China's rapid economic development, the GDP of Shandong Province has increased year by year, from 700 billion yuan in 1990 to nearly 3,100 billion yuan in 2008, as shown in Figure 1. The growth rate of Shandong Province's GDP exceeded 10% in 2000, and reached a peak of 24.3% in 2004. After 2004 the rate began to decline due to the macro-control. From 2006 to 2008, it has been controlled gently less than 20%.

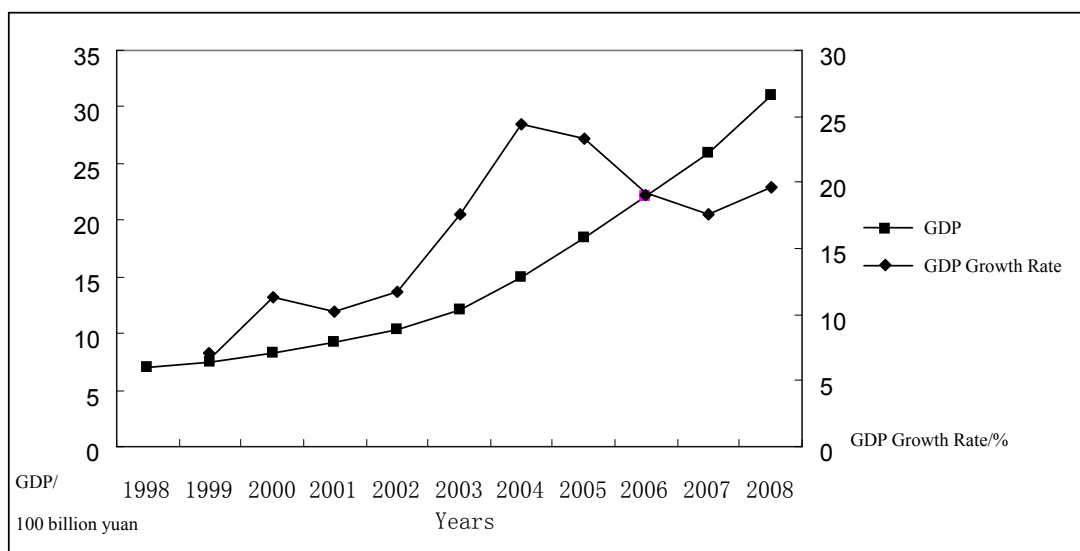


Figure 1. Shandong Province's GDP and Growth Rate 1998-2008

Economic structure affects energy consumption and different industries needs different energies. This article analyzes the proportion of each industry to the whole economy and based on the statistical classification we

disaggregate economy structure into agriculture, industry, construction, transportation, wholesale trade and other industries. The highest proportion of Shandong Province's economy is industrial output and there is an overall upward trend rising to 52% in 2008. The share of agriculture continues to decline from 17% in 1998 down to 9% in 2008. The proportion of construction keeps stable from 5% to 7%. The proportion of wholesale and retail trade and catering industry has been stable between 0.8% and 1%. The share of transportation is stable between 6% and 8%, of which a high in 2001 more than 7%, then lower in 2003, less than 6%.

Table 1. Shandong Province's economic structure and distribution

Years	Regional GDP	The First Industry	The Second Industry	Industry	Construction	The Third Industry	Transport, Storage, Post and Telecommunications	Wholesale, Retail Trade and Catering Services
1998	7021.35	1215.81	3408.06	3008.45	399.61	2397.49	437.37	735.63
1999	7493.84	1221.00	3644.32	3197.16	447.16	2628.52	484.65	787.90
2000	8337.47	1268.57	4164.45	3665.74	498.71	2904.45	545.13	856.94
2001	9195.04	1359.49	4556.01	4004.09	551.92	3279.53	657.57	972.33
2002	10275.50	1390.00	5184.98	4518.87	666.11	3700.52	655.64	1142.54
2003	12078.15	1480.67	6485.05	5706.71	778.34	4112.43	710.18	1283.70
2004	15021.84	1778.45	8478.69	7576.12	902.57	4764.70	969.13	1431.58
2005	18516.87	1927.85	10628.62	9568.58	1060.04	5960.40	1196.89	1653.87
2006	22077.36	2138.90	12751.20	11555.99	1195.21	7187.26	-----	----
2007	25965.91	2509.14	14776.53	13412.72	1363.81	8680.24	-----	----
2008	31072.06	3002.65	17702.17	16102.19	1599.98	10367.23	-----	---

Source: Shandong Statistic Yearbook (1998-2008)

It can be seen from Figure 2 that the energy consumption has grown fast since 2004, from 188.03 million tons of standard coal in 1998 to 538.21 million tons in 2008. As Shandong Province's energy consumption increases over the time, the energy intensity has fallen year by year from 26,780 tons of standard coal in 1998 down to 17,320 tons in 2008. That evident decrease trend shows the increase of energy efficiency.

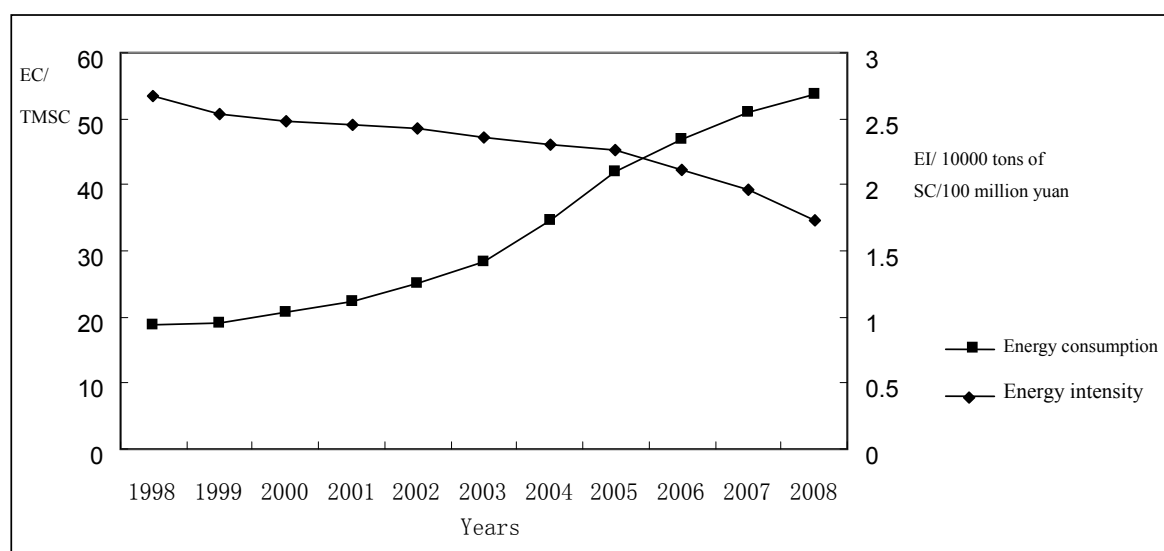


Figure 2. Energy consumption and energy intensity in Shandong Province in 1998-2008

Note: EC: energy consumption (thousand million standard coal);
EI: energy intensity (10000 tons of standard coal/ 100 million yuan)

4. Results of the Decomposition of Energy Consumption Change in Shandong Province

In this paper, we employ complete decomposition model to calculate the influencing effect that economic growth, economic structure and energy intensity impose on energy consumption in Shandong Province. We use relevant statistic data in Statistical Yearbook of Shandong Province from 1998 to 2008, including gross national product and the corresponding total energy consumption.

4.1 Decomposition and Comparison of Energy Consumption in Shandong Province

It can be seen from Table 2 that the coefficient of Shandong Province's economy growth has high level, respectively reaching 272%, 813% and 171%, indicating that economy growth is remarkably driving energy consumption in this province. The driving effect on Shandong Province's GDP is higher than the nation's average level. The nation's economic structure has imposed positive influence on energy consumption but lower than economic growth. The contribution rate of general impact of economic structure of is lower than the intensity impact and there are obvious fluctuations. Only from 2001 to 2005 it has promoted energy consumption growth, at the rest stage negative effect. Shandong Province has been committed to economic restructuring, and there is good trend, structural factors reducing energy consumption from 1998 to -6% to -26% in 2005. Appropriate economic structure is not only conducive to the rapid economic development but also help reduce energy consumption. Energy intensity coefficient is negative effectively offsetting the positive impact primarily driven by GDP growth. From the proportion of energy intensity to total energy changes, we can see the effect of energy intensity is significant in Shandong, which is related to Shandong Province's energy-intensive industrial transformation.

Table 2. Periodical decomposition for energy consumption in Shandong Province and comparison

Years	Regions	G_e	G Contribution Rate (%)	S_e	S Contribution Rate (%)	I_e	I Contribution Rate (%)	Real Increase
1998~2001	Shandong	4 155.8	(272)	-89.9	(-6)	-2 538.3	(-166)	1527.6
	Nation	61 397.8	(189.1)	8 411.2	(25.9)	-37 336.6	(-115)	32 472.4
2002~2005	Shandong	3 789.2	(813)	215.2	(46)	-3 538.3	(-759)	466.1
	Nation	53 792.3	(-6 123)	5 431.3	(-618)	-60 102.1	(6 841)	-878.5
2006~2008	Shandong	4 456.4	(171)	-665.1	(-26)	-1 185.1	(-45)	2 606.2
2006~2007	Nation	21 297.3	(118.8)	8 427.6	(4.7)	-4 215.8	(-23.5)	117 924.3

4.2 Periodical Analysis on Shandong Province's Energy Consumption Change Decomposition

From 1998 to 2001, the energy consumption intensity and GDP changes have played a leading role. It can be seen from Figure 3 that Shandong Province's economic growth effect curve is above the energy consumption curve every year, but the economic structure and energy intensity of the curve just the opposite. Shandong Province's GDP had a rapid growth from 1998 to 2000 and slowed in 2001. There was little change of structure influencing coefficient showing a decreasing trend, which was related with the increase of Shandong Province's industry and construction before and after 2001. The increase of energy-intensive industries will drive the growth of energy consumption. Shandong Province's energy intensity has shown a fast decline in 1998-1999, nearly 10%, consistent with the peak of coefficient curve of energy intensity in 1998-1999.

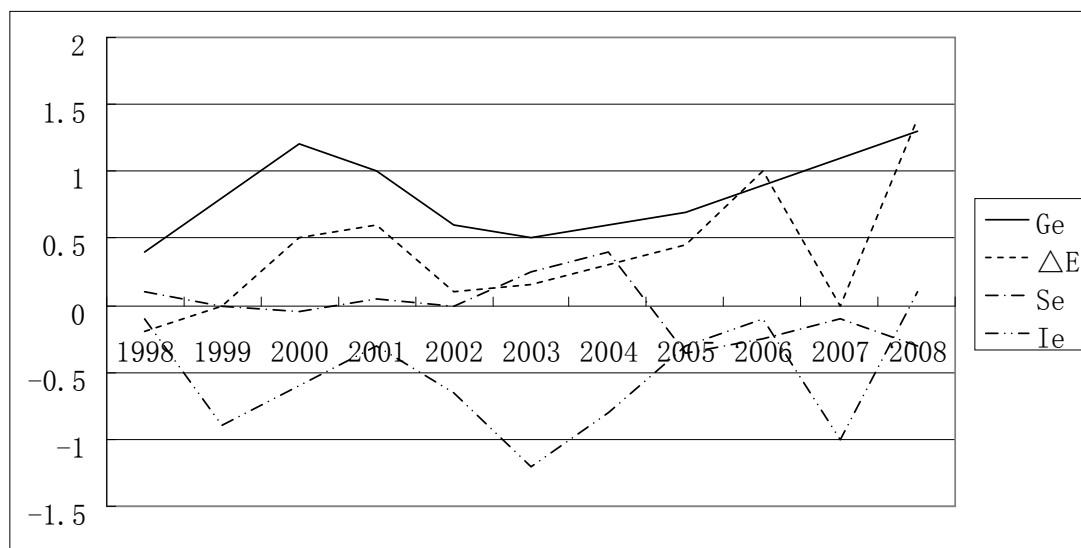


Figure 3. Historical influence curves of economic growth in Shandong Province

There was a remarkable change in energy intensity and economic structure from 2002 to 2005. Shandong Province's GDP growth rate has been between 10% and 20% from 2002 to 2005 and the influencing coefficient of energy intensity has maintained between 700 and 800. In 2005 the change of Shandong Province's energy consumption surpassed GDP influence coefficient showing a driving effect that is brought by structure change. Because the proportion of industry to GDP was 2% higher than previous year in 2005 the role of economic structure was highlighted. Driving effect of industry's development on energy consumption can be seen through historical fluctuant proportion of industry. The reducing degree of energy intensity was obvious in 2002 and 2003, both of which surpassed 10%, reaching the lowest in 2003. Shandong Province's energy consumption in these two years also witnessed a negative growth, affected by structure and energy intensity. From 2006 to 2008, GDP and economic structure had played offsetting roles. In this period Shandong Province's GDP growth rate had increased year by year and the influence coefficient of energy consumption change had witnessed a linear increase reaching a peak in 2008. In the respect of economic structure, the growing proportion of transportation and construction has not offset the effect of reducing energy consumption brought by lowering industry proportion. As industry's proportion decreased to 2% in 2008, there was an apparent reduction in structure influence coefficient. Shandong Province's energy intensity lowered 10% in 2007 as coincided Figure 3. The influence coefficient of energy intensity was positive but economic structure change played a negative role.

5. Policy Suggestions

Shandong Province's GDP effect coefficient, except for a few years, has been higher than 100%, obviously driving energy consumption growth. Energy intensity has offset energy consumption growth, as the average effect coefficient of energy intensity in Shandong Province's three stages is negative. The effect of economic structure is fluctuant.

Rapid economic growth inevitably stimulates energy consumption and we should try to identify specific measures to ease energy consumption from the respect of economic structure and energy intensity without sacrificing economic growth. Adjustment of industrial structure and product structure should be closely linked together. In addition to strategic adjustment of economic structure, economic growth pattern should be focused on, meanwhile improving product position in global value chain, optimizing economic efficiency, reducing resource consumption and decreasing environmental pollution are the focuses. Industry is the main driving force to promote economic development in Shandong Province, but the traditional mode of development characterized by high investment, huge energy consumption and serious pollution and low value-added products has not been suited to the development of conservation-minded society. As developing new industries, the advantages of local human resources should give full play and guide growth of technology-intensive industries to obtain structural energy conservation.

Practical approach is eliminating business entities characteristic of high energy- consumption and poor efficiency as taking relevant policies such as investment, taxation and so on so that the behavior of energy consuming can

pay the cost to ensure binding effect of market economy. Consequently, resources and elements will transfer to effective, low energy-consuming industries. It is noteworthy that the rapid development in construction and transportation industries in recent years has also contributed to the growth of energy consumption.

Under the constraints of market regulation, energy consumption is limited by total energy and environment situation. China's unbalanced economic development results in different energy efficiency in different regions. Compared to coastal areas characteristic of higher energy efficiency, Shandong Province's technology and equipment are relatively behindhand and many devices need to update and the energy efficiency of the system to be improved. Therefore, in respect of technological transformation and innovation in energy utilization, the national long-term development planning of R & D and industrialization should give adequate support, especially in the high energy consumption industries, such as heavy industry, transportation, etc., not only in energy transport and conversion process, but including end-use part, which will bring obvious impact on energy consumption in China. Shandong Province's investment in technological innovation is very impressive and achieved some success, but letting market-operating play a real guiding role is a fundamental way. Therefore as government guiding and investing fund, how to cultivate market innovative environment is also cannot be ignored.

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