Factors Decomposition of Energy Intensity: The case of Liaoning province in China

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Abstract- This paper introduces logarithmic mean Divisia index (LMDI) method on calculating factors contribution to energy intensity (EI) change and indicates that sector intensity contribution and efficiency contribution are different. Then this paper adopts LMDI to analyze the decrease of EI in Liaoning Province, the heavy industry base in northeast China. The results show that the sector intensity decline played a major role to the EI decline in Liaoning according to the division of three industries. When considering the product structure and product energy efficiency, the efficiency contribution share is 22.31%, and the product structure contribution share is 77.57% of the total EI decrease during 2000-2005. This revealed that structure change played a key role on the EI decline in Liaoning province. Finally, Reasonable proposals are given for Liaoning Province to achieve the energy-saving target in the 11th Five-Year Plan period.

Key-Words- Energy intensity; Sector intensity; Structure; Efficiency; Energy-saving

I. INTRODUCTION

With China's economy development, energy consumption (EC) grows rapidly. To keep the sustainable development of economy and society, Chinese Government takes energy-saving as a basic national policy in the 11th Five-Year Plan of national economy and society development, and puts forward a target of reducing 20% energy intensity (EI) by 2010 comparing to 2005.

The first and foremost task for China's energy-saving is to analyze the influencing factors of China's EI and their contribution to the EI change. Reference [1] employed a unique set of panel data for approximately 2500 of China's most energy intensive industrial enterprises including large and medium-sized during 1997–1999 and concluded that rising relative energy prices, research and development expenditures, and ownership reform in the enterprise sector, as well as shifts in China's industrial structure, emerge as the principal drivers of China's declining energy intensity. Reference [2] chose 36 industry sub-sectors from 1993 to 2003 of China as samplings to study based on improved index decomposition methods, ADMI and LMDI, the results was got that structure effect which was less than intensity effect decreased year by year before 1998 and turned to steady from 1999. Ma and Stern used logarithmic mean Divisia index (LMDI) technique to decompose change in energy intensity during 1980–2003, they found that technological change is confirmed as the dominant contributor to the decline in energy intensity and structural change at the industry and sector (sub-industry) level actually increased energy intensity during the period of 1980–2003[3]. However, reference [4] got contrary results based on factor decomposition method. Their findings showed that industry structure factors and industry intensity factors both played significantly positive role on China's EI decline. Reference [5] firstly gave a well-defined definition of the structure energy-saving and efficiency energy-saving, and then concluded that structure contribution was over 60% during 1995-2002 and structure factors promoted EI increase after 2002. Due to the different methods they chose, different definitions of efficient contribution, as well as time-frame, etc., the conclusions on China's EI change are not consistent.

In this paper, we put forward the difference between sector intensity contribution and efficiency contribution firstly. Then we adopt LMDI to analyze the factors and contribution to the EI change in Liaoning province during 1995-2005, the heavy industry base in Northeast China. Finally, on the basis of the results, some reasonable proposals are given for Liaoning Province to fulfill the energy-saving goal during the 11th Five-Year period.

II. LMDI DECOMPOSITION METHOD

Factors decomposition method for EI is a mathematical method that decomposes the factors' influence on EI, and calculates their contribution for EI change, which will provide decision support for government in energy-saving policymaking. Factors decomposition method was applied to the energy

 Paper submitted March 12, 2007; Revised August 18, 2007

field since late 1970s. In 1987, reference [6] firstly proposed the multiplicative version of the arithmetic mean Divisia index method (AMDI). Then a large number of relevant literature appeared [7]-[12]. In 1988, reference [13] proposed the additive version of AMDI. In 1998, reference [14] firstly put forward the additive version of the logarithmic mean Divisia index (LMDI). Then, in 2001, reference [15] proposed the multiplication version of LMDI. In 2004, Ang selected all decomposition methods for comparison, and recommended LMDI method for analysis EI [16]. In 2006, reference [17] recommended using the analytical limits of LMDI terms in cases of zero values. In 2007, Ang provided an analytical solution to the problem of negative values in the data set [18]. With the issue resolved, the LMDI approach can be generally applied to any decomposition situation.

Factors decomposition model in EI is as shown as formula (1)

$$I = \frac{E}{Y} = \frac{\sum_{i=1}^{k} E_i}{Y} = \frac{\sum_{i=1}^{k} I_i Y_i}{Y} = \sum_{i=1}^{k} I_i S_i \quad (1)$$

where I is EI; E is the whole EC; Y is GDP; E_i is the EC of i sector; I_i is the sector intensity in i sector; S_i is the value added proportion of sector i in GDP; k is the number of sectors.

The EI change of the additive version of LMDI can be expressed as formula (2)

$$\Delta I_{tot} = \Delta I_{str} + \Delta I_{int} + \Delta I_{res} \quad (2)$$

where ΔI_{tot} is total EI change; ΔI_{str} is the EI change caused by structure changes; ΔI_{int} is the EI change caused by sector intensity changes; ΔI_{res} is the residuals of incomplete decomposition.

$$\Delta I_{tot} = I^t - I^0 \quad (3)$$

$$\Delta I_{srt} = \sum_i L\left(\frac{E_i^t}{Y^t}, \frac{E_i^0}{Y^0}\right) \ln\left(\frac{S_i^t}{S_i^0}\right) \quad (4)$$

$$\Delta I_{\mathrm{int}} = \sum_i L\left(\frac{E_i^t}{Y^t}, \frac{E_i^0}{Y^0}\right) \ln\left(\frac{I_i^t}{I_i^0}\right) \quad (5)$$

In formula (3) and (4), L(x, y) can be expressed as:

$$L(x, y) = \frac{(y - x)}{\ln\left(\frac{y}{x}\right)} \quad (6)$$

It should be emphasized that, in this method, EI change is decomposed into sector intensity factors and structure factors. Some scholars believe that sector intensity change is the result of technological advances, so it was directly called technological progress (efficiency) factors. However sector EI is a comprehensive factor, which is determined by technological advances, product structure in the sector and other factors. According to the logic of decomposition method, sector intensity is also determined by sub-sector intensity, product structure and product energy efficiency, etc. In order to get exact contribution share of EI change, efficiency contribution should be distinguished from sector intensity contribution.

III. CASE STUDY

According to the annual Liaoning Statistical Yearbook from 1995 -2005, we get the date of GDP, value added of three industries, value added of each sub-sectors in industry sector, EC, etc [19]. To meet the need for analysis, we take 2005 as the base year. GDP and value added are all transferred into comparable values.

A. Trend of EI Change in Liaoning Province

Table 1 shows the EI change of Liaoning Province during 1995-2005. The total EI (exclude residents' energy consumption) declined from 273.11tce/ (million Yuan) in 1995 to 161.37tce/ (million Yuan) in 2005. The primary industry's EI dropped from 26.95tce/ (million Yuan) in 1995 to 18.36 tce/ (million Yuan) in 2004, and increased to 26.11tce/ (million Yuan) in 2005. The secondary industry's EI dropped from 550.43tce/ (million Yuan) in 1995 to 285.39tce/(million Yuan) in 2005. The tertiary industry's EI decreased from 44.83tce/(million Yuan) in 1995 to 31.08tce/(million Yuan) in 2004 and increased to 44.46 tce/(million Yuan) in 2005.

Table 1 EI of Liaoning Province in 1995-2005(tce/million Yuan)

Year	The Primary Industry EI (EI_1)	Decline Rate (%)	The Secondary Industry EI (EI_2)	Decline Rate (%)	The Tertiary Industry EI (EI_3)	Decline Rate (%)	Total EI	Decline Rate (%)
1995	26.9		550.4		44.8		299.9	
1996	28.9	-7.18	508.2	7.67	41.6	7.14	277.2	7.57
1997	27.0	6.55	460.2	9.45	37.3	10.44	248.5	10.38
1998	24.6	8.72	411.1	10.66	34.6	7.34	221.5	10.86
1999	24.0	2.52	377.3	8.23	32.4	6.16	204.6	7.62
2000	23.6	1.87	377.8	-0.15	38.9	-20.01	209.2	-2.26
2001	22.8	3.08	361.7	4.26	45.2	-16.17	201.3	3.80
2002	20.7	9.23	327.6	9.44	40.6	10.20	182.2	9.46
2003	19.0	8.47	318.9	2.65	31.6	22.09	175.3	3.82
2004	18.4	3.25	309.7	2.88	31.1	1.71	174.7	0.34
2005	26.1	-42.23	303.9	1.86	44.5	-43.04	183.4	-4.98
1995-2000		**2.64**		**7.25**		**2.79**		**6.95**
2000-2005		**-2.07**		**4.26**		**-2.71**		**2.60**
1995-2005		**0.31**		**5.77**		**0.08**		**4.80**

Fig. 1 shows the EI change in Liaoning province during 1995-2005. It indicates that between 1995 and 1999, there is a sustained, rapid EI decline. After 2000, this trend slowed down a little. The secondary industry EI is generally consistent with total EI, during 1995-2004, the primary and tertiary industries' EI kept a slight decline, but in 2005, they rebounded at varying degree.

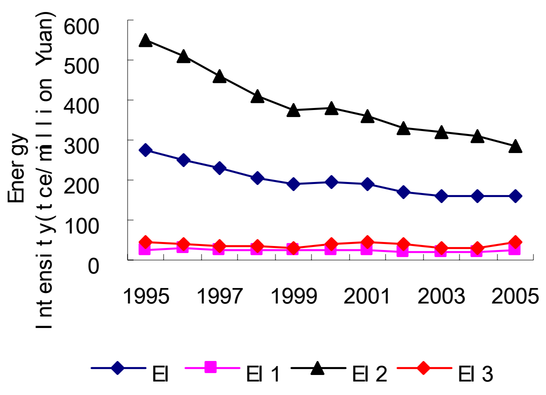

Fig. 1 Trend of EI in Liaoning Province

B. LMDI Method Analysis of EI

LMDI method is applied to decompose the EI of Liaoning Province, and the decomposition results are shown in Table 2.

The calculated results in Table 2 indicate that:

(1) The calculated residual share by LMDI method is close to zero except for certain years, which show the effectiveness of decomposition.

(2) During 1995-1999, the total EI declined rapidly, in which industrial intensity accounted for the major share of contribution, while the industrial structure had negative effect during 1996-1997, 1998-1999. During 1999-2000, both industrial EI and industrial structure promoted the total EI ascending. After 2000, the total EI decline slowed down, in which both industrial EI and industrial structure promoted the total EI decline during 2000-2002, and the structural contribution was negative during 2003-2005.

Table 2 Factors contributions to EI decline of Liaoning province during 1995-2005

Year	EI changes (tce/million Yuan)	Structure Share (%)	Industry intensity share (%)	Residual Share (%)
1995-1996	-21.86	9.11	91.92	-1.02
1996-1997	-20.96	-17.33	113.71	3.62
1997-1998	-25.11	6.17	94.94	-1.10
1998-1999	-15.94	-3.48	102.62	0.86
1999-2000	5.44	60.97	51.67	-12.64
1995-2000	**-78**	**-6.15**	**104.77**	**1.38**
2000-2001	-7.00	29.57	70.82	-0.39
2001-2002	-18.27	2.80	97.54	-0.34
2002-2003	-6.99	-15.98	113.62	2.35
2003-2004	-0.85	-444.46	541.57	2.89
2004-2005	-0.19	-2701.88	2832.78	-30.90
2000-2005	**-33**	**-25.35**	**125.23**	**0.12**

(3) As mentioned above, sector intensity is a comprehensive index, which is determined by technological progress, sub-sector structure adjustment and other factors. Sector intensity contribution is not equal to efficiency contribution.

According to the decomposition method introduced above, the sub-sector structure contribution was partly included in the sector energy efficiency contribution, thus the efficiency contribution was overestimated, and the structure contribution was underestimated.

In order to determine efficiency contribution and structure contribution in EI change, we decomposed sector intensity, and separated EC per unit product from sector intensity as the energy efficiency index. Table 3 lists EC per unit product of six heavy EC industries [20].

C. *Results of factor Contribution*

Table 3 Unit Product EC of Six Heavy Energy Intensive Industries in 2000 -2005

Industries	Unit	2000	2001	2002	2003	2004	2005	Decline rate (%)
Electric power								
coal consumption of power supply	gce/kWh	392	385	383	380	376	374	0.9
Iron and Steel								
EC for steel production	kgce/t	898	865	823	777.71	761	741.05	3.8
Nonferrous Metals								
EC of copper smelting	kgce/t	1277.2	1079.5	1016.1	957.0	1056.2	779.8	9.4
Electricity consumption of Aluminium	kWh/t	15480	15470	15362	15026	14795	14622	1.1
EC of lead smelting	kgce/t	721.0	685.4	607.1	606.9	633.4	629.8	2.7
EC of Electrolytic Zinc	kgce/t	2306.9	2050.2	1887.7	1889.6	2013.1	1996.7	2.8
Petroleum								
EC of ethylene	kgoe/t	768.24	748.13	719.62	707.68	692.15	690	2.1
EC of Refinery	kgoe/t	79.74	78.25	78.32	76.06	73.50	73.0	1.8
Chemicals								
EC of synthetic Ammonia (Imported)	kgce/t	1326.6	1345	1385	1346.1	1320	1300	0.4
EC of synthetic Ammonia (medium)	kgce/t	1892	1890	1881	1946	1870	1860	0.3
EC of synthetic Ammonia (small size)	kgce/t	1801	1808	1799	1782	1771	1760	0.5
Caustic soda (divide)	kgce/t	1563	1480	1465	1463	1462	1460	1.4
Caustic soda (ion-exchange membrane)	kgce/t	1090	1069	1057	1073	1060	1050	0.7
Soda (Ammonia Soda)	kgce/t	468	465	464.3	457	455	450	0.8
Soda (the alkali)	kgce/t	313	315	322.4	313.5	310	307	0.4
Building Materials								
EC of cement	kgce/t	172	169	162	158	154	149	2.8
EC of plate glass	kgce/t	30	24	24	23.2	23	22	6.0

Based on the classification of three industry sectors, in which the industry sector is further classified into 27 sub-sectors, we get 29 sectors in total. Then we decompose EI into efficiency contribution share and structure contributions share with LMDI method. The decomposition results are listed in Table 4.

Table 4 Contributions of efficiency and structure for EI Changes in Liaoning Province

Year	EI changes (tce/million Yuan)	Structure share (%)	Efficiency share (%)	Residual Share (%)
2000-2001	-7.00	83.17	17.23	-0.39
2001-2002	-18.27	94.33	6.01	-0.34
2002-2003	-6.99	79.09	18.56	2.35
2003-2004	-0.85	-30.29	127.39	2.89
2004-2005	-0.19	-419.14	550.05	-30.90
2000-2005	**-33.31**	**77.57**	**22.31**	**0.12**

The calculated results show that among the contributors of the EI decline, the structure share is 77.57% and the efficiency share is 22.31% during 2000-2005. During 2000-2003, structure contribution exceeds 70%. After 2003, the proportion of heavy industry in the national economy of Liaoning Province increased. Extraordinary development of the heavy energy-intensive industries seriously hampered the EI decline. During 2003-2005, though the efficiency contribution promotes the EI decline, the heavy industrial structure promoted the EI increase. It illustrates that the influence of structural change on the EI change in Liaoning province is significant. Thus, in order to achieve the 20% energy-saving target, it is of great importance to adjust industry structure, sector structure of industry and product structure for Liaoning province, and enhance energy efficiency at the same time base on technological progress.

IV. CONCLUSION

In this paper, we distinguish sector intensity contribution from efficiency contribution, adopt LMDI method to analyze the influencing factors in the EI change of Liaoning Province during 1995-2005, and get the following conclusions.

Firstly, according to the division of three industries, the sector intensity decline played a major role in the EI decline of Liaoning Province during 1995-2005, while the adjustment of the industrial structure played a minor role, and even plays a negative part.

Furthermore, during the period of 2000-2005 in Liaoning province, the contribution of structure and efficiency to the EI decline are 77.57% and 22.31% respectively and the contribution of structure exceed that of efficiency. This reveals that structure adjustment play an important role in the EI decline. Though the energy statistic data on the level of products is not comprehensive and the calculation results are to be further improved, it indicates the way to fulfil the 20% energy-saving target in the 11th Five-Year Plan period for Liaoning province. And it also puts forward a new idea for research in this field in the future.

Last but not least, it is key work to adjust the industrial structure for Liaoning Province to realize the energy-saving goal in the 11th Five-Year Plan period.

ACKNOWLEDGEMENT

The work described in this paper was supported by research grants from Humanities and Social Science project of the Ministry of Education of China (Project number: 07JA790092) and National Science Foundation of China (70771039, 70671042).

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