ISSN 1749-3889 (print), 1749-3897 (online)
International Journal of Nonlinear Science
Vol.12(2011) No.1,pp.80-85

Decomposition of Factors Impact on Carbon Emission for China Based on LMDI

Zhengming Wang[1] *, Dongdong Jing[2], Zhengnan Lu[3]
[12]School of Finance, Jiangsu University, 212013, Zhenjiang
[3] College of Business Administration, Jiangsu University, 212013, Zhenjiang
(Received 5 June 2011,accepted 29 July 2011)

Abstract: As earth climate warms rapidly, the problem of carbon emissions has become a universal concern, the study of the factors involving carbon emissions will be the basis in finding the way to the reduction. LMDI established a framework to study the change in emission intensity and its mechanism. Using the extend Kaya Identity to decompose the driving factors into energy structure, energy intensity, economic and population, the logarithmic mean Divisia index (LMDI) model was employed to analyze factors contribute to the growth of the carbon emission in China during the period of 1996-2009. The results showed that economic effect is the main reason contributes to the increase of carbon emissions, while the energy intensity plays an important role in emission reduction, energy structure and population are no so important.

Keywords: energy consumption; carbon emissions; LMDI

1 Introduction

With the improvement of human productivities and people's life after the industrial revolution,greenhouse gas (GHG) emissions such as carbon dioxide have grown rapidly,so is the greenhouse effect in the atmosphere. It is confirmed that greenhouse gas emission was the main reason that caused the global warming and the extremely climate events. Greenhouse effect is now becoming a global risk and hazard as a negative externality. But how could we deal with it? First of all, we must make it clear what factors contribute the carbon emission growth, and then we might find a carbon emission reduction policy. The paper is a decomposition analysis to the factors of carbon emission growth in China in this context.

2 Related literature reviews

Structural Decomposition Analysis (SDA) is a widely accepted tool to deal with the environmental issues [1-2]. For instance, Guo (2010) designed an extend input-output system model of import-competition economy-energy-environment (3E),by using two-level nested method of SDA to decompose carbon emission in China during 1992-2007 [1]. Sun et al. (2010) used time series decomposition analysis to investigate factors contribute carbon emission intensity changes 1995-2005 in China [2]. Though the SDA has a relative advantage by using input-output tables, the using of it was constraint by the time-long preparation for the tables (5 year). The logarithmic mean Divisia index (LMDI) could solve the problem properly.

The logarithmic analysis was first raised by Laspeyres, which could date back to 1871. But it was not widely used until Ang and Liu (1998) solve the problem of residual in Index Decomposition Analysis (IDA) by using the logarithmic mean Divisia index analysis [3]. As people becoming more and more concerned about the environmental pollution and global warming since 1990s, the LMDI model was introduced in these studies. More recently, factors of carbon emission in China were also analyzed with this method. Xuetal. (2006) analyzed the influence of energy structure, energy efficiency and economic development to carbon emissions per capita based on LMDI, they concluded that contribution rate of energy structure and energy efficiency restraining to carbon emissions per capita is as the down "U" [4]. Zhao (2010) analyzed

*Corresponding author. *E-mail address*: zhmwang@ujs.edu.cn

IJNS.2011.08.15/515

the impaction of Jiangsu FDI on carbon emission in 1985-2008 [5]. Qian(2010) constructed a complete LMDI model,and identified the factors that influence the changes of energy-related carbon emission in Inner Mongolia [6].

Based on the extend Kaya Identity, LMDI method was employed in this paper to decompose the driving factors of the Energy-related carbon emission in China during the period of 1996-2009.

3 Empirical methodologies

3.1 Extend Kaya Identity

The Kaya Identity was first raised by Professor Yoichi Kaya on an UN Intergovernmental Panel on Climate Change (IPCC) seminar[6-7]. The equation linked carbon emission and its driving factors,and constructed an equation which can be expressed in terms of economic,policy and population factors. (See Eq. 1)

$$C = \frac{C}{PE} \times \frac{PE}{GDP} \times \frac{GDP}{POP} \times POP \tag{1}$$

Where C is the aggregate carbon dioxide emission, PE is the energy consumption, GDP is the Gross Domestic Production, and POP is the population size.

In order to study the driving factors to the carbon emission deeply, we modified the Kaya Identity. Assume i is fuel types, we can get:

$$C = \sum_i C_i = \sum_i (\frac{C_i}{PE_i} \times \frac{PE_i}{PE} \times \frac{PE}{GDP} \times \frac{GDP}{POP} \times POP) = \sum_i f_i \times s_i \times e \times g \times p \tag{2}$$

Where C_i is the CO_2 emission arising from fuel i, PE_i is the consumption of fuel i, f_i(=C_i/PE_i) is the coefficient of fuel i, s_i(=PE_i/PE) is the energy consumption share of fuel i,$e(= PE/GDP)$ is the energy intensity,g(=GDP/POP) is the per capita gross domestic product, $p = POP$ is the total population of China.

3.2 The logarithmic mean Divisia index (LMDI) model

The general index decomposition analysis (IDA) identity is given by

$$C = \sum\nolimits_i C_i = \sum\nolimits_i x_{1,i} x_{2,i} \cdots x_{n,i} \tag{3}$$

Later Ang proposed a decomposition method that gives perfect decomposition by solving the residual problem [3,8]. In the LMDI approach, the general formulate can be expressed in the form of additive decomposition or multiplicative decomposition.

In the additive decomposition, the equation is given by

$$\Delta C_{tot} = C^T - C^0 = \Delta C_{x_1} + \Delta C_{x_2} + \cdots + \Delta C_{x_n} \tag{4}$$

Where

$$\triangle C_{x_k} = \sum\nolimits_i \frac{C_i^T - C_i^0}{\ln C_i^T - \ln C_i^0} \ln(\frac{x_{k,i}^T}{x_{k,i}^0}). \tag{5}$$

In the multiplicative decomposition, the equation is given by

$$D_{tot} = C^T / C^0 = D_{x_1} D_{x_2} \cdots D_{x_n} \tag{6}$$

Where

$$D_{x_k} = \exp(\sum\nolimits_i \frac{(C_i^T - C_i^0)/(\ln C_i^T - \ln C_i^0)}{(C^T - C^0)/(\ln C^T - \ln C^0)} \ln(\frac{x_{k,j}^T}{x_{k,j}^0})). \tag{7}$$

As we can get the same result from additive decomposition and multiplicative decomposition,in this paper we choose the additive decomposition. So from Eq. (4), we can have:

$$\Delta C_{tot} = C^T - C^0 = \Delta C_{str} + \Delta C_{int} + \Delta C_{eco} + \Delta C_{pop} \quad (8)$$

The subscripts tot, str, int, eco and pop respectively denote the effects associated with overall activity, structural, energy intensity, economic and population.

4 Data sources

The research period starts in 1996 and ends in 2009. The CO_2 emission is calculated in terms of energy consumption and the carbon emission coefficients. The physical and standard final consumption data were taken from China Energy Statistical yearbooks,which contained 19 energy fuel types. As the final energy consumption contained primary and secondary consumption,we have to convert secondary energy such as electricity and heat into coal equivalent. We can get the carbon emission coefficients data from IPCC. The GDP and population data were collected from China statistical yearbook 2010. The real GDP for this period is calculated based on the indices (1996=100) of Gross Domestic Product. We classified the final energy consumption sectors into six departments: agriculture; industry; construction; transport and telecommunications services; wholesale, retail and catering service and other.

Table 1 carbon emission coefficient

Energy types	carbon emission coefficient (104tC/104tce)	Energy types	carbon emission coefficient (104tC/104tce)
Raw Coal	0.7559	Fuel Oil	0.6185
Cleaned Coal	0.7559	Other Petroleum products	0.5857
Briquettes	0.7559	LPG	0.5042
Coke	0.8550	Natural Gas	0.4483
Other Coking Products	0.6449	Coke Oven Gas	0.3548
Crude Oil	0.5857	Refinery Gas	0.4602
Gasoline	0.5538	Other Gas	0.3548
Kerosene	0.5714	Diesel Oil	0.5921

Data sources: calculated from 2006 IPCC guidelines for national greenhouse gas inventories.

5 Results and discussion

The energy consumption grows from 1234.74 million tons in 1996 to 2773.98 million tons in 2009. The carbon emission grows from 3.25 billion tons in 1996 to 7.20 billion tons in 2009, in which industry sector carbon emission grows to 5.22 billion tons about twice the emission in 1996. The carbon emission in different sectors except industry can be seen blow.

Table 2 shows the result derived from LMDI analysis based on extended Kaya Identity. Figure 2 shows the cumulate effects of China's carbon emission result from decomposition.

We can see from the empirical result that carbon emission in China has increased ever since 1996 but slowed after 2005. From the decomposition results we can calculate that energy structural factor contribute about -1.665% to the overall increase of carbon emission, energy intensity factor contribute -67.909%, economic factor contribute 159.926% while population contribute 9.648%.

(1) energy structural effect performed a negative effect, because China has been advocating energy efficient enterprises, encouraging new energy industries and has achieved a good result recently. Figure 2 shows that the cumulate energy structural effect is very low; it means their still has room to improve in the future.

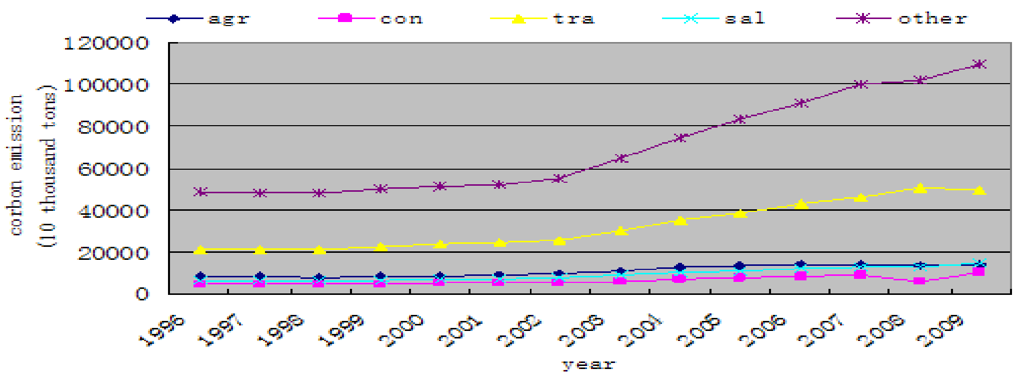

Figure 1: carbon emission in different sectors

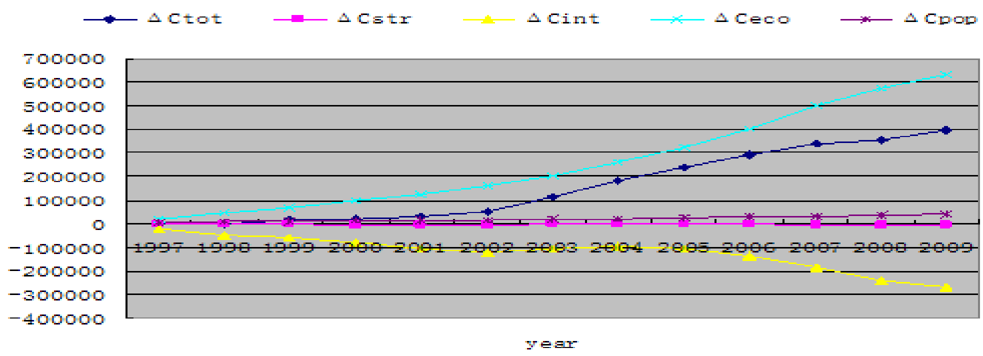

Figure 2: effects of cumulate carbon emission

Table 2 Impact of different factors on the change of China's industrial CO_2 emissions

Year	ΔC_{tot}	ΔC_{str}	ΔC_{int}	ΔC_{eco}	ΔC_{pop}
1996-1997	-1219.14	-1873.26	-24179.2	21565.08	3268.274
1997-1998	225.4303	-849.916	-23092.7	21200.93	2967.13
1998-1999	13540.77	-557.084	-10716.5	22102.33	2712.056
1999-2000	8549.628	-1251.28	-23395.1	30599.8	2596.169
2000-2001	7349.306	-178.773	-25128.4	30220.18	2436.26
2001-2002	20890.07	-375.32	-15542.9	34456.36	2351.948
2002-2003	63123.8	1777.758	17041.25	41866.69	2438.109
2003-2004	69790.19	322.9688	10529.62	56165.24	2772.362
2004-2005	55942.06	1527.211	-13971.3	65233.25	3152.86
2005-2006	54755.88	-202.154	-28783.4	80622.96	3118.45
2006-2007	47744.48	-4316.65	-50144.2	98887.59	3317.79
2007-2008	15944.25	-1361.97	-56510.4	70390.78	3425.8
2008-2009	38226.18	764.5027	-24254	58175.95	3539.762
1996-2000	21096.69	-4531.53	-81383.6	95468.14	11543.63
2000-2005	217095.4	3073.845	-27071.7	227941.7	13151.54
2005-2009	156670.8	-5116.27	-159692	308077.3	13401.8
1996-2009	394862.9	-6573.96	-268147	631487.1	38096.97

(2) energy intensity effect played an important role in the reduction of carbon emission. As it shows in Table 2 that the factor turned positive because of technical bottlenecks or economic growth, but later it turned negative after 2004.

(3) economic effect was a main reason to the increase of carbon emission,as the significant economic growth in China. We can explain this phenomenon by, first because of the relatively lower economic growth and polluting industries account a great proportion of the economy, and second technical backwardness of our country and corporate emissions awareness is low.

(4) population increase and consumption patterns will lead to increased demand for energy consumption of life, resulting in the growth of carbon emissions. But in general, the population effect is relatively small and not significant, and therefore is less important to our carbon emission reduction.

6 Policy implications

China government has announced a 40 to 45 percent reduction in carbon intensity from 2005 levels before 2020, which imposed a pressure to explore new ways for carbon reduction. In order to reduce carbon emission in the future we should concentrate on industry, which accounts 72% of carbon emission. And in another aspect,the LMDI decomposition implies that we can significantly reduce carbon emission by increase energy intense effect and reduce economic effect. Several measure China must take:

First, put priority on structure optimization and industrial upgrading. In this knowledge economy, technology-driven industry has accounted about 72.8% in OECD countries. In contrast,industrial structure of China still shows a character of high energy consumption high pollution and resource-based. In order to change this situation, China has to upgrade its position in global value chain,and establish its own comparative advantage by encouraging high-tech and high-value-added businesses. At the same time, local government should encourage the development of eco-economy, and take some measure to reduce the carbon emission in the traditional industries [9].

Second, encouraging technical innovation and develop new energy sources. Most technology used in carbon emission was introduced from abroad, because of its high cost,large enterprise size and technical personnel, which can't afford by firms in China. New energy sources like wind power, solar could change the energy structure in China. So, it's reasonable for government to encourage firms to develop new energy sources by provide financial support.

Third, establish a carbon emission market by learning experiments from other emission trade systems. It is estimated by UN and World Bank that the carbon trading market value in 2012 will exceed oil market to 150 billion dollars [10]. Europe Union has established its own emission trade system in 2005, which is the world's most important market mechanism for reducing GHG emissions. Through carbon emission trading system, firms can explore technological progress and at the same time earned by selling emission quotas. China is now participating in the Clean Development Mechanism (CDM) as a non-mandatory reduction country of "Kyoto Protocol". Therefore, the establishment of China's carbon emission trading system is a general trend.

Acknowledgements

Thank the National Natural Science Foundation of China, project number 71173094, and Nation Statistics Research Plan Project (2010), project number 2010258, and the Jiangsu University 9th Batch of Students in Research Funded Project (2010), project number: 09C071 of funding for this article.

References

[1] Guo. An analysis of the increase of CO_2 emission in China [J]. *China Industrial Economics*, 12(2010): 1-12.

[2] Sun, Zhao et al. Research on carbon emission estimation and factor decomposition of China from 1995 to 2005 [J]. *Journal of Natural Resource,* 25(2010) (8): 1284-1295.

[3] Ang, B.W., Zhang, F.Q.,K.H., Choi. Factorizing changes in energy and environmental indicators through decomposition. *Energy*,23(1998): 489-495.

[4] Xu et al. Decomposition model and empirical study of carbon emissions for China [J]. *China Population Resources and Environment*,16(2006) (6):158-161.

[5] Zhao. The decomposition model of the impact of FDI on carbon emissions intensity for Jiangsu province [J].

[6] Qian et al. Decomposition analysis on changes of energy-related CO_2 emission in Inner Mongolia [J].*Technology Economics,* 29(2010) (12): 77-84.

[7] Feng, Chou. Economic Analysis of CO2 Emission Trends in China [J]. *China Population Resources and Environment*,18(2008) (3): 43-47.

[8] B.W., Ang. The LMDI approach to decomposition analysis: a practical guide. *Energy Policy*,33(2005): 867-871.

[9] Lu. The trend of the world's industrial structure changes and the upgrading of china's industrial structure [J]. *Journal of Northwest University*,40(2010) (3):100-103.

[10] Guo,Peng. Carbon Market [M]. Science Publishing House, Beijing, 2009.