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Empirical analysis of the evolution characteristics and influential factors of carbon emissions in hebei province

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ABSTRACT

Based on Kaya formula, we established carbon emission estimation model. LMDI decomposition method was used to establish the decomposition model about increase factors of carbon emissions in Hebei, and make a quantitative analysis of the effects from energy structure, population, economic growth, energy intensity and industrial structure etc. on carbon emissions in 1999-2010, in Hebei Province. Study found that economic growth, the population were positive determinant factors; energy structure, energy intensity were the decisive factors in the negative, weak influence of industrial restructuring. Then low-carbon economic politic recommendations were put forward correspondingly.

KEYWORDS

Carbon emissions;
Factor analysis;
Economic growth;
Low carbon.

INTRODUCTION

Early in the 90s, the characteristics and influential factors of carbon emissions have caused some scholars' attention. The famous idea of Kaya formula was that carbon emissions were mainly affected by four factors[7]. Then based on this formula, carbon emissions were pointed out that nine factors were contributed to it[1]. Also decoupling indicators were established based on driving force to research the relationship between economic growth and greenhouse gas emissions[11]. The Logarithmic Mean Divisia Index (LMDI) method of complete decomposition is used to examine the role of three factors affecting the evolution of CO2 emissions from electricity generation in seven countries[10]. Energy integration had a remarkable effect on the emission reduction[12]. A study was conduct on China's economic development and carbon emissions based on environmental kuznets curve (EKC) and derivative curve[4]. An increment factor decomposition model is established for carbon emissions in Jiangsu province[9]. One study examines the long-run relationship between carbon emissions and energy consumption, income and foreign trade in the case of China[6]. A paper investigates the driving forces, emission trends and reduction potential of China's carbon dioxide (CO2) emissions based on a provincial panel data[5]. One paper analyzes the relationship between the changes in energy consumption structure and the carbon emissions in Hebei Province[11].

Hebei province is located in China's core area of the "beijing-tianjin-Hebei bohai economic circle", containing rich iron ore, oil, coal etc primary energy and wind energy, solar energy, biomass energy — clean and renewable energy resources. It is experiencing the rapid development of urbanization and industrialization. However, high carbon industry in Hebei province is still the dominant one supporting the development of economy. In order to find out the driving factors and solutions of carbon emissions, this paper uses empirical analyses of carbon emission characteristics and influential factors by a new fomula based on Kaya formula to alleviate the contradiction between economic development and environmental resource.

DATA AND METHODOLOGY

Data

This paper selects GDP per capita as the indicator of economic growth, all kinds of energy accounted for the proportion of the total energy as the measure of energy structure, energy intensity as a measure of energy efficiency, the carbon intensity as technology factors, Industrial energy intensity as industrial structure. Energy consumption, energy structure index, population, carbon emissions and carbon emissions per capita to reflect the strength of carbon emissions in Hebei province. The data from the People's Republic of statistics bulletin in 1999-2010.

Methodology

Based on the Kaya formula, an analytical model is established about the carbon emissions to analyze the relationship between carbon emissions and influential factors. Japanese scholars - MaoYang, put forward the famous idea of Kaya formula in 1990:

$$\mathrm{C} = \frac{C}{E} \times \frac{E}{GDP} \times \frac{GDP}{P} \times P \qquad (1)$$

Where C is carbon emissions, E is one-time energy consumption; GDP is gross domestic product; P is population. Carbon emission model can be changed into the following formula based on the basic formula from Xu (2006):

$$C = \sum_i Ci = \sum_i \frac{Ei}{E} \times \frac{Ci}{Ei} \times \frac{E}{GDP} \times \frac{GDP}{P} \times P = \sum_i S_i \times ef_i \times P \times PG \times EI \qquad (2)$$

$$EI = \sum_j \frac{E_j}{GDP_j} \times \frac{GDP_j}{GDP} = \sum_j I \times IS \qquad (3)$$

Refer Ang of the decomposition method of LMDI without residual, as well as formula (2), carbon emissions changes from year t to year t +1 can be expressed as:

$$\Delta EI = EI_{t+1} - EI_t = \Delta EII + \Delta EIS \qquad (4)$$

$$\Delta C = C_{t+1} - C_t = \Delta C_S + \Delta C_{ef} + \Delta C_p + \Delta C_{PG} + \frac{\Delta E_{II}}{\Delta EI}\Delta C_{EI} + \frac{\Delta E_{IS}}{\Delta EI}\Delta C_{EI} \qquad (5)$$

$$\Delta C_S = \sum_i L(C_i^{t+1}, C_i^t)\ln(\frac{S_i^{t+1}}{S_i^t}) \qquad (6)$$

$$\Delta C_P = \sum_i L(C_i^{t+1}, C_i^t)\ln(\frac{P^{t+1}}{P^t}) \qquad (7)$$

$$\Delta C_{PG} = \sum_i L(C_i^{t+1}, C_i^t)\ln(\frac{PG^{t+1}}{PG^t}) \qquad (8)$$

$$\Delta C_{EI} = \sum_i L(C_i^{t+1}, C_i^t)\ln(\frac{EI^{t+1}}{EI^t}) \qquad (9)$$

$$L(C_i^{t+1}, C_i^t) = \frac{C_i^{t+1} - C_i^t}{\ln(C_i^{t+1}) - \ln(C_i^t)} \qquad (10)$$

$$\Delta EII = \sum_j L(E_j^{t+1}, E_j^t)\ln(\frac{EII_j^{t+1}}{EII_j^t}) \qquad (11)$$

$$\Delta EIS = \sum_j L(E_j^{t+1}, E_j^t)\ln(\frac{EIS_j^{t+1}}{EIS_j^t}) \qquad (12)$$

$$L(E_j^{t+1}, E_j^t) = \frac{EI_j^{t+1} - EI_j^t}{\ln(EI_j^{t+1}) - \ln(EI_j^t)} \qquad (13)$$

Where C_i is carbon intensity of i kind of energy; E_i is consumption of i kind of energy, where E_i / E is the proportion of consumption of i kind of energy. Per capita GDP, reflects economic development and macroeconomic indicators in life measuring economic growth. Energy intensity is unit GDP energy consumption, the ratio of primary energy usage or final energy usage and the gross domestic product. S_i is energy structureÿ ef_i is the Coefficient of carbon emissions, PG is per capita GDP,EI represents energy intensity, E_j / GDP_j is industrial energy intensity, represented by I: industrial structure GDP_j / GDP is represented by IS. C^{t+1} is the carbon emissions in year t+1; C_i^{t+1} is the carbon emissions in year t+1 of I kind of energy; ΔEII indicates the effect of industrial energy intensity; ΔEIS means the industrial structure effect; ΔC_S means that carbon emissions caused by energy structure changes; ΔC_P means changes in carbon emissions caused by the change in population size; ΔC_{PG} changes in carbon emissions due to changes in economic growth; ΔC_{EI} means changes

in carbon emissions from the combined effects of industrial energy intensity and industrial structure. '
Carbon emissions are calculated based on the formula (1) – (13). According to the IPCC hypothesis, carbon emissions factors (ef_i) of some energy are the same. Values of carbon emissions factors mirror the research data of NDRC's energy research institute, see TABLE 1.

TABLE 1 : Carbon emission factors of all kinds of energy

Index	coal	oil	gas	Water and electricity
CO2 emission factor (tons of coal/ten thousand tons of standard coal)	0.7476	0.5825	0.4435	0

Characteristics of carbon emissions

Figure 1 reflects a long-term development trend of carbon emissions in 1999-2010 in Hebei province, figure 2 shows the relationship between carbon emissions and per capita GDP.

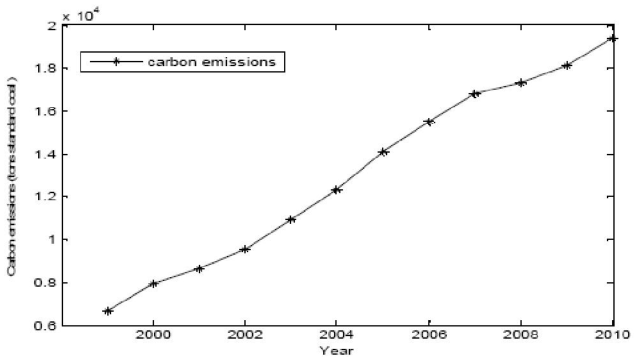

Figure 1 : Development trend of carbon emissions in 1999-2010 in Hebei province

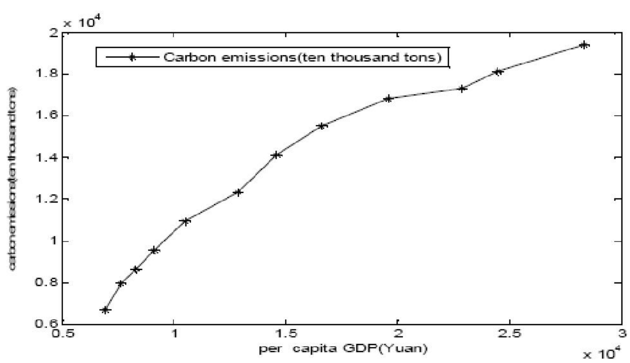

Figure 2 : The inverted U shaped curve existed in carbon emissions and per capita GDP in 1999-2010 in Hebei

View from figure1 and figure2, carbon emissions have the following features in Hebei province:

(1) The carbon emissions show a rising trend in Hebei province. According to the law changes in the slope of the graph line, it can be roughly divided into three stagesÿThe first stage is 1999-2002, slow rising phase; the second stage for carbon emissions in 2003-2007 is fast incremental growth. The third stage is carbon emissions' decreasing growth stage in 2008-2010. Compared the data through calculation, the carbon emissions in 2010 in Hebei province accounted for 9.36% of the national total emissions, annual carbon emissions in 1999-2010 accounted for 8.88% of national annual carbon emissions, was 1.69 times as the national annual carbon emissions.

(2) Carbon emissions in Hebei province, presented reversed U relationship along with per capita GDP's increasing. As economic growth (per capita GDP), carbon emissions showed a rapid rise at first, then a slow rise, the dynamic inverted U type relationship revealed that there was an environmental kuznets inverted U type mechanism in some degree between economic growth and carbon emissions. After 2008 years, the increase of carbon emissions showed a tendency of rise caused by economic growth. Supposedly, Hebei carbon emissions in Hebei will increase to 252,863,900 tons by 2015[8].

Analyses of influential factors of carbon emissions

Carbon emissions of final energy consumption in Hebei was divided into five driven factors include economic growth, industrial structure, population, energy consumption structure change, energy intensity change, to analyze the various factors on the impact of incremental carbon emissions in Hebei. (AV represents Annual variation, CA represents cumulative amount Unit: Ten thousand tens)

As can be seen from TABLE 2, the cumulative effect of the energy structure is -1,528,900 tons; demographic changes of population on carbon emissions amounted to 12,005,000 tons; the cumulative impact from economic growth on carbon emissions amounted to 189,278,600 tons, significantly affected; effect from changes in energy intensity on carbon emissions as -75,165,100 tons, significant impact; industrial structure changes on the impact of carbon emissions amounted to 807,300 tons, the impact is not very big. The total increase in carbon emissions 123,597,000 tons in 1999-2010. The following are analyses of the impact on carbon emissions from all factors.

(1) Economic growth factor. From analyses above, it can be found a close relationship between per capita GDP and carbon emissions. This paper addressed per capita GDP as the independent variable and carbon emissions as the dependent variable, and make regression analysis between per capita GDP and carbon emissions, results shown in TABLE 3.

TABLE 2 : Decomposition Analysis on the incremental effect of carbon emissions in Hebei

Year	Energy structure		Population		Economic increase		Energy intensity		Industrial structure		Carbon emissions	
	A V	C A	A V	C A	A V	C A	A V	C A	A V	C A	A V	CA
1999-2000	18.03	18.03	65.83	65.83	719.49	719.49	-711.23	-711.23	141.40	141.40	233.52	233.52
2000-2001	18.55	36.59	31.17	97.00	729.59	1449.08	-54.13	-765.36	-65.05	76.35	660.13	893.65
2001-2002	-12.34	24.25	48.50	145.50	797.75	2246.83	-42.72	-808.08	17.96	94.31	809.16	1702.81
2002-2003	32.06	56.31	51.44	196.94	1459.56	3706.39	-318.37	-1126.45	226.15	320.47	1450.83	3153.64
2003-2004	-43.27	13.04	68.44	265.38	2386.09	6092.48	-1319.23	-2445.68	186.60	507.07	1278.63	4432.27
2004-2005	20.49	33.53	81.28	346.65	1671.27	7763.74	1485.56	-960.13	-182.21	324.86	3076.38	7508.65
2005-2006	-6.58	26.95	101.30	447.96	1909.84	9673.58	-708.64	-1668.77	103.03	427.89	1398.95	8907.60
2006-2007	25.98	52.93	105.10	553.06	2660.24	12333.82	-1591.42	-3260.19	91.81	519.70	1291.71	10199.31
2007-2008	-11.13	41.80	112.79	665.85	2666.61	15000.43	-2448.33	-5708.52	299.32	819.02	619.26	10818.57
2008-2009	-3.08	38.72	113.76	779.61	1191.37	16191.80	85.97	-5622.55	-732.39	86.63	655.64	11474.21
2009-2010	-191.60	-152.89	420.90	1200.50	2736.07	18927.86	-1893.97	-7516.51	-5.90	80.73	1065.50	12539.70

TABLE 3 : Tthe linear regression relationship between carbon emissions and per capita GDP

Regression equation	R Square	Adjusted R Square	F	Std. error	t	Sig.
Y=4253.933+0.585x	0.944	0.938	167.945	0.045	12.959	0.000

Seen from table 3, the goodness-of-fit decision coefficient R^2 is 0.944 in the regression model, the revisedis 0.938 which represented fitting degree is very good, showed that economic growth and carbon emissions are highly relevant. Make a variance analysis, F = 167.945, and sig. = 0.000, indicating a linear relationship between carbon emissions and economic growth. Regression coefficient is 0.585, the error of the regression coefficient is 0.045, the value of t in regression test is 12.959, the sig. Value is zero, consistent with variance's analysis, regression coefficient is significant.

(2) Energy intensity and carbon intensity factors. From the curve's shape of energy intensity in 1999-2010 in figure 3, energy intensity peak in 2003 in Hebei province then began to gradually reduce. But compared with other big provinces good in energy and economy in 2010, such as Guangdong 0.664 tons of standard coal/ten thousand Yuan, Shanghai 0.712, Beijing 0.582, Jiangsu 0.734, and Hebei province is as high as 1.35, more than 2 times as above provinces, it is a big gap.

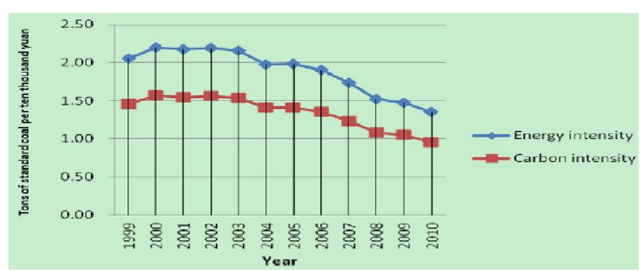

Figure 3 : Energy intensity and carbon intensity development trend chart in 1999-2010 in Hebei

As shown in figure 4, the energy intensity of second industry is much higher than the first and third industries, the fluctuation range of the second industry is very large in our country in recent ten years which can be seen from graphic trendWhile the first and third industrial energy intensity in the first and third industries is reduced year by year, down to 0.3 in 2009.the downward trend of the lines indicates that the development in the first and third industries can still maintain high-income and low-carbon development pattern in the future period of time. In recent years, some areas adjust measures to develop eco- tourism and sightseeing agriculture; The strength of the life energy consumption is also gradually reducing, mainly the change of energy consumption by residents' life in Hebei province, such as combustion, heating.

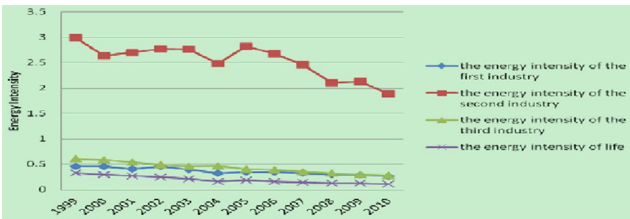

Figure 4 : The energy intensity in three industries and life in 2000-2009 in Hebei province

(3) Energy consumption structure factor. Coal has occupied the absolute dominant position in the energy consumption structure in Hebei, in which the carbon emissions produced by coal combustion accounted for 85% of the total emissions, the average level of coal consumption accounted for 84.11% of average total energy consumption, far higher than the average level of national coal consumption 69.8%; average level of oil consumption accounts for 6.85% of the average total energy consumption; Natural gas for 0.72% —far below the national overall consumption ratio 2.9%; Water and electricity consumption accounted for only 0.07% of the total energy consumption, while the national consumption ratio of water and electricity is 7.1%. The present situation of the energy of "rich coal, lean oil, less gas" is the main reason for the phenomenon in Hebei province, just as shown in figure 5.

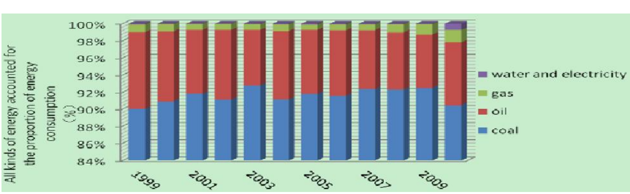

Figure 5 : Energy consumption structure in 1999-2010 in Hebei province

(4) Industrial structure factor. As shown in figure 6, the average proportion of the second industrial energy consumption in 1999-2010 in Hebei province was as high as 77.25%, the average levels of energy consumption in first and third industries are only 3.13% and 11.18%, while the contribution rates to GDP of three industries in 2010 were 12.6%, 52.5% and 34.9% respectively. It can be found that the level of energy consumption and the level of output in the second industry don't match in Hebei province, thus the industry system presents the characteristics of high carbon.

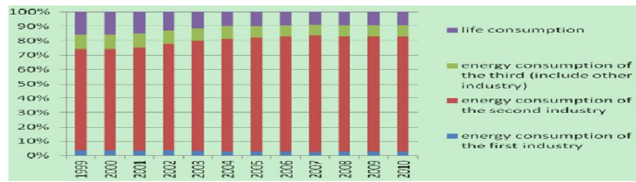

Figure 6 : The proportion of energy consumption of three industries in 1999-2010 in Hebei province

POLICY RECOMMENDATIONS AND CONCLUSIONS

The policy suggestions

(1) Establish a low carbon economic system. Hebei is a big economic province with high energy consumption, need a good low carbon system to support. First, enact a series of laws clearly which define related concept, scope, and the relevant measures; Through direct control, tax regulation and financial subsidies; Also a financial policy support is very essential, through financial means to promote the development of low carbon industry.

(2) Optimize industrial structure. The proportion of the second industry in Hebei province is large, industrial structure is not reasonable. It is important to upgrade industries, improve the utilization efficiency of energy; weed out those backward, smaller, polluting enterprises, strengthen cooperation, introduce advanced technology, optimize production process. Promote the industrial structure optimization and upgrading actively.

(3) Optimize the energy structure. Increase the research and investment of wind power technology, as soon as possible to create high quality equipment suitable for air and ground environment in Hebei, reduce wind power generating cost, accelerate its

popularization and application. To make full use of abundant wind power, solar and other renewable energy in Zhangjiakou and Chengde, and expand the use of alternative energy such as biomass, and finally achieve the reduction of carbon emissions. Besides, vigorously promote the application of solar photovoltaic equipments by government subsidy.

(4) Strengthen the innovation of low carbon technologies. The government should increase investment in related research units, enhance the ability of scientific research and raise the level of research. Introduce advanced and applicable technology, to achieve a low-carbon development of economy at a level of jump with low cost, optimize allocation of resource and utilization of energy, participate in international cooperation actively.

CONCLUSION

Through the analyses above, we can get the following conclusions:

(1) Per capita carbon emissions and carbon emissions in Hebei province present a rising trend, with the existence of a high degree of linear relationship between economic growth and carbon emissions, which are the results of the combined effects of industrial structure, economic growth, carbon intensity, energy intensity and structure of energy consumption.

(2) The light and wind industry group in cities such as Baoding and Handan has already begun to come into scale, the development of new clean energy industrial clusters is very good to reduce carbon intensity. But high-carbon industry plays a big part in heavy industry, and the inhibition of new energy is not enough to offset high carbon emissions.

(3) Some economic policies play an important role in guiding industries and enterprises to produce in a way of low-carbon.

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