Study of the Correlation Between Carbon Consumption and Economy Development in Provinces of China

HUANG Xueli
School of Business Administration, Jiangsu University, P.R.China, 212013
Nanxu College, Jiangsu University of Science and Technology, P. R. China, 212003
hxueli@yahoo.com.cn

Abstract: In this study, carbon emission factors of raw coal and its derivative products in China were estimated based on reference methods provided by IPCC. In addition, End-user carbon consumption and GDP averaged carbon consumption for 30 provinces of China were calculated based on the end-user energy consumption data of these provinces in 2007 and the default parameters recommended by IPCC. Based on these results, together with the GDP per capita index, provinces under the study were classified to three groups according to the correlation between carbon consumption and economy development of these provinces: coordinative, rather coordinative and not coordinative. Analysis shows that the composition of the carbon consumption and carbon production efficiency are two major factors that impact the coordination between carbon consumption and economy development in the studied provinces. Furthermore, strategies for coordinating carbon consumption and economy development at province level in China were proposed, which include appropriate policy guidance, adjusting industry structure, improving carbon production efficiency and advocating of sustainable life style.
Keywords: Carbon consumption, economy development, carbon production efficiency

1 Introduction

Global warming and the corresponding ecological and environmental changes caused by carbon emission due to the consumption of fossil fuel raise environmental restrictions to the economic development of human beings. Current study shows that there is a close correlation between the carbon consumption and economy development in China and controlling the carbon emission restrains the economy development(ZHANG Lei,2003[1]; TAN Dan,2008[2]; CHEN Wenying, 2004[3]; WANG Can,2005[4]). IPCC pointed out that carbon emission equals to the difference between carbon consumption and carbon stored[5]. Studying the current status of carbon consumption and economy development is significant for coordinating carbon emission and economy development. However, as far as we know, there are only few reports related to such study in China, including one study focusing on the carbon consumption in Beijing(XING Fang-fang, 2007[6]). This paper discussed the current situation of carbon consumption and economy development of 30 provinces in China, as well as their causes.

2 Study Strategy, Data Sources and Calculation Method

2.1 Study Strategy

(1) Carbon consumption, GDP averaged carbon consumption, and average GDP were chosen as the representative indices (represents the environmental effects of carbon emission, carbon production efficiency level and other local economy development level, respectively) to establish the framework for the study of the correlation between carbon consumption and economy development.
(2) Carbon consumption, GDP averaged carbon consumption, carbon consumption of different businesses and GDP per capita were calculated according to the energy sources of the end-user energy consumption in China in 2007, Gross local products and populations of the investigated provinces.
(3) By comparing the calculation results obtained in (2) to the average levels of the representative indices selected in (1), the correlation between carbon consumption and economy development for the provinces included this study were discussed and strategies and suggestions to coordinate carbon consumption and economy development were proposed.

2.2 Data Sources

Data used for this study were mainly from the categorized end-user energy consumption data and carbon emission factors for different energy sources covering 30 provinces in China except Tibet, Taiwan, Hong Kong and Macao. Data for categorized end-user energy consumption are cited from reference 7[7]. Part of the carbon emission factors of different energy sources are cited from reference 5[5]. Population of each province and GDP values of different businesses are from reference 8[8].

2.3 Calculation Methods

2.3.1 Calculation of carbon consumption

Energy sources of the end-user energy consumption in China include raw coal, cleaned coal, other washed coal, briquettes, coke, coke oven gas, other gas, crude oil, gasoline, kerosene, Diesel Oil, Fuel Oil, LPG, Refinery Gas, Natural Gas, Other Petroleum products, Other Coking products, Electricity, Heat, etc. These energy sources were classified as 4 categories and calculation was performed using the reference methods recommended by PICC.

carbon consumption (Gg C)

= ∑ Apparent Energy Consumption (by fuel type in TJ)× Carbon emission factor (by fuel type in t C/TJ) × 10^{-3}

= ∑ (Consumption× Conversion Factor×Carbon Emission Factor)/1000--------Equation 1

(1) Raw Coal, Cleaned Coal, Other Washed Coal, Briquettes, coke,Coke Oven Gas,Other Gas

①Selection of the Conversion Factor data

Conversion Factors for Raw Coal、Cleaned Coal, Other Washed Coal, Coke, Coke Oven Gas were obtained from the Average Low Calorific Values reported by reference 7. Since the Average Low Calorific Value for Briquettes was not provided by the reference, Average Low Calorific Value of Washed Coal was used for the calculation of Briquettes in this study. The mean value of Other Coal Gas in reference 7 was used as the Average Low Calorific Value for other gases.

②Calculation of carbon emission factor data

According to equations recommended by IPCC, one obtaines[5].

Cc = 32.15 - (0.234×Hv) --------Equation 2

where Cc is the carbon emission factor in t C/TJ and Hv is the Low Calorific Value of the coal, which were the obtained from reference 7.

③Calculating carbon consumption using equation1.

(2) Crude Oil, Gasoline, Kerosene, Diesel, Fuel Oil, Liquefied Petroleum Gas, Refinery Gas, Natural Gas, Other Petroleum products, Other Coking products

①Using the Average Low Calorific Value from reference 7 as Conversion Factor data;

②Using the default values from reference 5 as the carbon emission factor data;

③Calculating carbon consumption using equation 1.

(3) Electricity

①Converting Electricity Consumption to Coal Equivalent according to Electricity Consumption *0.357 kg Coal Equivalent / kilowatt hour [9] ;

②Calculating the amount of Raw Coal and Crude Oil used for generating electricity（electricity consumption after conversion times the corresponding fraction of the electricity generated by Raw Coal and Crude oil in the total amount of electricity that are generated, which are 0.798 and 0.0185, respectively. Other fractions are contributed from the electricity generated by nuclear energy, wind and biomass energy） [10];

③Converting the Raw Coal and Crude oil amount from Coal Equivalent (obtained from (2) to the respective materials;

④Calculating the carbon consumption of crude oil and coal according to their respective methods described in (A) and (B).

(4) Heat

① Converting Heat to Coal Equivalent according to Heat consumption*0.03412kg Coal Equvalent/10^5Jole;
② Converting the Coal Equivalent obtained in(1) to Raw Coal amount;
③ Calculating the carbon consumption by Raw Coal according to the method for calculating carbon consumption by Raw Coal described in (A).
2.3.2 Calculation of the GDP Averaged carbon consumption
GDP Averaged carbon consumption =carbon consumption/GDP
2.3.3 Determination of average levels of the representative indices
The average levels of the representative indices were determined by the mean values of the average of the total national carbon consumption, the average of the national GDP averaged carbon consumption and 2005-2007 national GDP per capita.

3 Results and Cause Analysis

According to the results of the calculation in section 2, the 30 provinces involved in this study were separated into 6 groups, as shown in table 1.

3.1 Elucidation of the Calculation Results

Group 1 includes Tianjin, Beijing, Heilongjiang and Shanghai. For all of these provinces, all of three investigated indices (total carbon consumption, GDP averaged carbon consumption and GDP per capita) are superior to their corresponding average levels, indicating little effects of carbon emission on the environment, high carbon production efficiencies and high levels of the local economy development. To conclude, the carbon consumption coordinates the economy development very well in these provinces in the year 2007.
Group 2 includes Zhenjiang, Jiangsu, Guangdong and Shandong provinces. For these provinces, the total carbon consumption is higher than the average level, but GDP averaged carbon consumption and GDP per capita are both better than the average level. Considering the fact that the local gross product values of these provinces are the top four provinces in China, the huge economy scale applies great impact on the environment. However, the better GDP averaged carbon consumption than the average level indicates a high carbon production efficiency. As a result, for these provinces, the carbon consumption still coordinates the economy development pretty well.
Group 3 include Fujian, Chongqing, Jiangxi, Shanxi, Guangxi, Sichuan and Hainan. For these provinces, the total carbon consumption and GDP averaged carbon consumption are both superior to the corresponding average levels, but the GDP per capita is lower than the average level. Considering their high carbon productivity, which, to some extent, may warranties an effective control of the total carbon consumption during the development of economy in the future, the carbon consumption is considered to coordinate the economy well.
Group 4 include Anhui, Jilin, Qinghai, Ningxia, Gansu, Xinjiang, Guizhou and Yunnan. Their total carbon consumption values are superior to the average level, but the GDP averaged carbon consumption and GDP per capita are lower than the average levels. Although the low GDP per capita indicates more space for the future economy development, the low carbon production efficiency suggests that unless the carbon production efficiency can be improved effectively, there will be a rapid increase in the carbon consumption resulted from the rapid development of economy in the future. Consequently, carbon consumption of these provinces is considered not coordinating the economy development well.
Group 5 include Liaoning, Hebei and Inner Mongolia. Although GDP per capita numbers for these provinces are higher than the average level, the total carbon consumption and GDP averaged carbon consumption are both higher than the average levels. This means that the during the economy development, these provinces didn't pay enough attention to improve the environment. The economy development of these provinces greatly affects the environment. If the mode of the economy can not be changed appropriately in the future, the conflict between the carbon consumption and economy development will be worse. Consequently, carbon consumption of these provinces is considered not coordinating the economy development well.

Group 6 include Hunan, Hubei, Shanxi and Henan. For these provinces, all the three indices are worse than the average levels, indicating great effects of carbon emission on the environment, low carbon productivity and low local economy development level. As a result, carbon consumption of these provinces is considered not coordinating the economy development well.

To summarize, the 30 provinces under the investigation can be grouped into coordinative, rather coordinative and not coordinative as regard to the correlation between carbon consumption and economy development. In the following section, the causes responsible for such different correlation will be discussed based on the analysis of GDP averaged carbon consumption of different businesses and the composition of carbon consumptions.

3.2 Cause Analysis

3.2.1 Analysis of the carbon production efficiency of different businesses

(1) Industrial carbon productivity is the key point to coordinate carbon consumption and economy development.

Observing from group 1 to group 4, 5 and 6, where the coordination between carbon consumption and economy development degrades (shown in table 1), the carbon productivity keep decreasing while there is no apparent trends observed for other businesses and average residential consumptions among the provinces belonging to different groups. In addition, carbon consumption for different businesses and average residential carbon consumption for provinces in group 1 are even kept at relatively high levels. This means the key point to effectively coordinate the carbon consumption and economy development in China is to increase the carbon productivity.

(2) The carbon production efficiency of Transport, Storage and Post also affects the coordination between carbon consumption and economy development.

Figure 1 shows that the carbon consumption caused by transport, storage and post, and residential consumption is the second only to industry. However, the carbon production efficiency of transport, storage and post and residential consumption for all the provinces are the lowest except for industry. Therefore, monitoring the carbon production efficiency of transport, storage and post and residential consumption can effectively reduce the carbon emission. The development of the economy will expand the needs for transportation, storage and post. Therefore, monitoring the carbon production efficiency will be beneficial for China to control the carbon consumption in the future.

3.2.2 Analysis of the carbon consumption composition

Figure 1 shows that for all the provinces under the investigation, industrial carbon consumption dominates the total carbon consumption. However, for all the provinces in group 1, the weight of industrial carbon consumption is lighter than that for those in other groups, while at the same time, wholesale, Retail trade and Hotel, Restaurants contributes more to the total carbon consumption compared to provinces in the other groups. Therefore, the more the businesses with less GDP averaged carbon consumption contribute to the total carbon consumption, the better the carbon consumption coordinates the economy development.

4 Strategy Study

4.1 Promoting the Use of High Technology to Improve the Carbon Product Efficiency.

As discussed above, the carbon product efficiency is low for industry and transport, storage and post in China. However, under the current situation, controlling the consumption of energy may restrict the development of economy. Therefore, improving the carbon production efficiency by introducing and applying novel and high techniques is a practical chose for China to compromise the carbon consumption and economy development. Estimated by the data collected in 2007, if the industrial carbon emission per product is reduced by 50%, the total carbon emission will be reduced by 20% and 35% for Beijing and Liaoning, respectively.

4.2 Developing Modern Service Businesses and Adjusting the Industry Structure

At present, industry is still the key business that drives the development of the economy in China.

Although service businesses, such as Wholesale, Retail Trade and Hotel, Restaurants consume less carbon, the proportion they contribute to the local gross product are still relatively small. Therefore, developing modern service businesses not only cultures new growth points for economy, which maintains sustainable and steady growth of the economy, but also effectively controls the carbon consumption. To conclude, adjusting the industry structure is one of the important strategies for provinces in China to realize the coordination between carbon consumption and economy development.

4.3 Advocating Sustainable Life Styles

Table 1 shows that the residential carbon consumption per capita varies greatly among provinces, suggesting the impact of life style on carbon consumption. The slogan for 2008 World Environment Day, as appointed by the United Nation Environment Program was "Kick the Habit! Towards a Low Carbon Economy", which advocates a sustainable life style. As pointed out by the "quantitative standards for the potential of nation-wide energy saving" edited by the department of science and technology of China, nation-wide participation of 36 routine activities for both energy saving and emission reduction can result in a decrease of 200 million tons in carbon dioxide emission. Vigorously propagating the impact of life style on environment to the public, reducing residential carbon consumption, advocating low energy consumption, low pollution, and low emission in routine life will also be helpful for the coordination between carbon consumption and economy development.

5 Conclusion

End-user carbon consumption and GDP averaged carbon consumption for 30 provinces of China were calculated based on the end-user energy consumption data of these provinces in 2007. Reference methods provided by IPCC, as well as the default parameters recommended by IPCC or estimated parameters were used for the calculation. In addition, the current situation of carbon consumption and economy development in these provinces in 2007 were discussed from the aspect of the effects of carbon emission on environment, carbon production efficiency and local economy development level. Major conclusions include:

(1)Tianjin, Beijing, Heilongjiang and Shanghai are among the best in China as regard to the coordination between carbon consumption and economy development in 2007. Carbon consumption coordinates economy development well in Zhejiang, Jiangsu, Guangdong, Shandong, Fujian, Chongqing, Jiangxi, Shanxi, Guangxi, Sichuan, and Hainan provinces. In Anhui, Jilin, Qinghai, Ningxia, Gansu, Xinjiang, Guizhou, Yunnan, Hunan, Hubei, Shanxi, Henan, Liaoning, Hebei, Inner Mongolia, carbon consumption doesn't coordinate economy well.

(2)Carbon production efficiency of Industry, transport, storage and post and the composition of carbon consumption determined by the industry structure impact the coordination between carbon consumption and economy development. Industrial carbon production efficiency is the key point for the coordination.

(3)Coordination between carbon consumption and economy development can be established by adjusting industry structure, improving carbon production efficiency and advocating sustainable life style.

References

[1]. ZHANG Lei. Economic Development and Its Bearing on CO_2 Emissions. Acta Geographica Sinica, 2003, 58(4): 629-637(in Chinese)

[2]. AN Dan, HUANG Xian-jin. Correlation Analysis and Comparison of the Economic Development and Carbon Emissions in the Eastern, Central and Western Part of China. China Population, Resources And Enviroment,2008,18(3):54-57(in Chinese)

[3]. CHEN Wen ying, GAO Peng fei, HE Jian kun. Impacts of future carbon emission reductions on the Chinese GDP growth. J Tsinghua Univ. (Sci & Tech), 2004, 44(6):744-747(in Chinese)

[4]. WANG Can, CHEN Jining, ZOU Ji. Impact assessment of CO_2 mitigation on China economy

based on a CGE model. J Tsinghua Univ. (Sci & Tech) , 2005(45)12:1621-1624(in Chinese)
[5]. IPCC/IEA/OECD/UNEP. Greenhouse gas inventory reporting instruction, revised 1996 IPCC guidelines for national greenhouse gas inventories,vol.1-3.Bracknell,UK:IPCC WGI Technical Support Unit,1997
[6]. XING Fang-fang, OUYANG Zhi-yun, WANG Xiao-ke, DUAN Xiao-nan, ZHENG Hua, MIAO Hong. Inventory of Final Energy-Carbon Consumption and Its Structure in Beijing. Environmental Science, 2007, 28(9):1918-1923(in Chinese)
[7]. National Bureau of Statistics of China. China Energy Statistical Yearbook 2008. Beijing: China Statistics Press,2008(in Chinese)
[8]. National Bureau of Statistics of China. China Statistical Yearbook 2006, 2007, 2008. Beijing: China Statistics Press, 2006-2008(in Chinese)
[9]. State Information Center. Chinese electric power profession monthly operational report2007/12.http://download.china.cn/ch/pdf/080512-2/dianli.pdf(in Chinese)
[10]. Chinese Academy of Science sustainable development study team. China sustainable development Strategy report2009. Beijing: China Science Press, 2009:210(in Chinese)

Table 1 Correlation between carbon consumption and economy development for 30 province in China

Coordinative status	group	Region	Appraisal frame			Carbon consumption per GDP					Consumption per capita	
			Impacts on environment	Carbon production efficiency	Local economy level	Farming, Forestry, Animal Husbandry, Fishery & Water Conservancy	Industry	Construction	Transport, Storage and Post	Wholesale, Retail Trade and Hotel, Restaurants	Residential Consumption	
											Urban	Rural
coordinative	1	Tianjin	√	√	√	17.94	28.63	7.57	34.44	11.95	11.9	8.56
		Beijing	√	√	√	25.92	24.7	6.27	32.87	8.9	11.97	25.73
		Heilongjiang	√	√	√	8.19	31.8	1.13	66.48	10.52	11.76	2.45
		Shanghai	√	√	√	16.47	20.75	10.16	20.44	7.37	8.97	13.55
	2	Zhejiang		√	√	4.34	30	2.2	17.03	2.67	4.36	3.43
		Jiangsu		√	√	8.04	29.07	5.19	21.08	6.38	5.38	6.31
		Guangdong		√	√	6.17	21.91	5.29	29.02	6.47	6.1	5.61
		Shandong		√	√	8.05	37.25	3.86	19	4.75	6.07	4.42
rather coordinative	3	Fujian	√	√		6.39	32.13	2.87	17.31	4.53	6.45	4.97
		Chongqing	√	√		12.84	39.7	6.08	18.03	5.05	3.52	3.65
		Jiangxi	√	√		4.81	34.87	0.9	18.14	3.92	3.52	2.04
		Shaanxi	√	√		7.76	35.95	3.67	30.96	14.21	6.34	1.67
		Guangxi	√	√		7.76	35.95	3.67	30.96	14.21	6.34	1.67
		Sichuan	√	√		7.76	35.95	3.67	30.96	14.21	6.34	1.67
		Hainan	√	√		3.61	32.47	3.68	12.52	6.58	2.71	1.32
not coordinative	4	Anhui	√			3.17	54.38	3.58	21.07	4.64	4.3	1.87
		Jilin	√			6.69	53.85	8.9	46.15	10.79	8.77	4.26
		Qinghai	√			2.87	95.54	5.43	37.68	6.88	6.97	4.63
		Ningxia	√			11.83	142.43	6.58	32.63	10.55	6.75	5.85
		Gansu	√			16.03	75.81	6.89	28.79	5.49	6.31	4.41
		Xinjiang	√			12.15	53.57	4.52	51.75	14.75	11.18	3.34
		Yunnan	√			7.56	70.83	6.81	36.19	4.15	4.97	2.81
		Guizhou	√			14.65	112.99	7.4	36.17	19.11	5.6	7.44
	5	Liaoning			√	6.73	46.03	5.24	51.86	3.89	13.1	5.71
		Hebei			√	7.67	65.42	3.56	15.77	5.2	6.55	5.54
		Inner Mongolia			√	22.89	77.89	8.42	24.77	8.75	7.26	6.39
	6	Hunan				8.43	53.44	5.62	20.55	13.66	3.82	3.6
		Hubei				7.16	57.07	8.86	33.45	8.05	6.36	3.56
		Shanxi				22.89	77.89	8.42	24.77	8.75	7.26	6.39
		Henan				5.14	44.58	1.3	20.88	3.22	5.63	3.46

Notes：√ means the value is superior to the average level

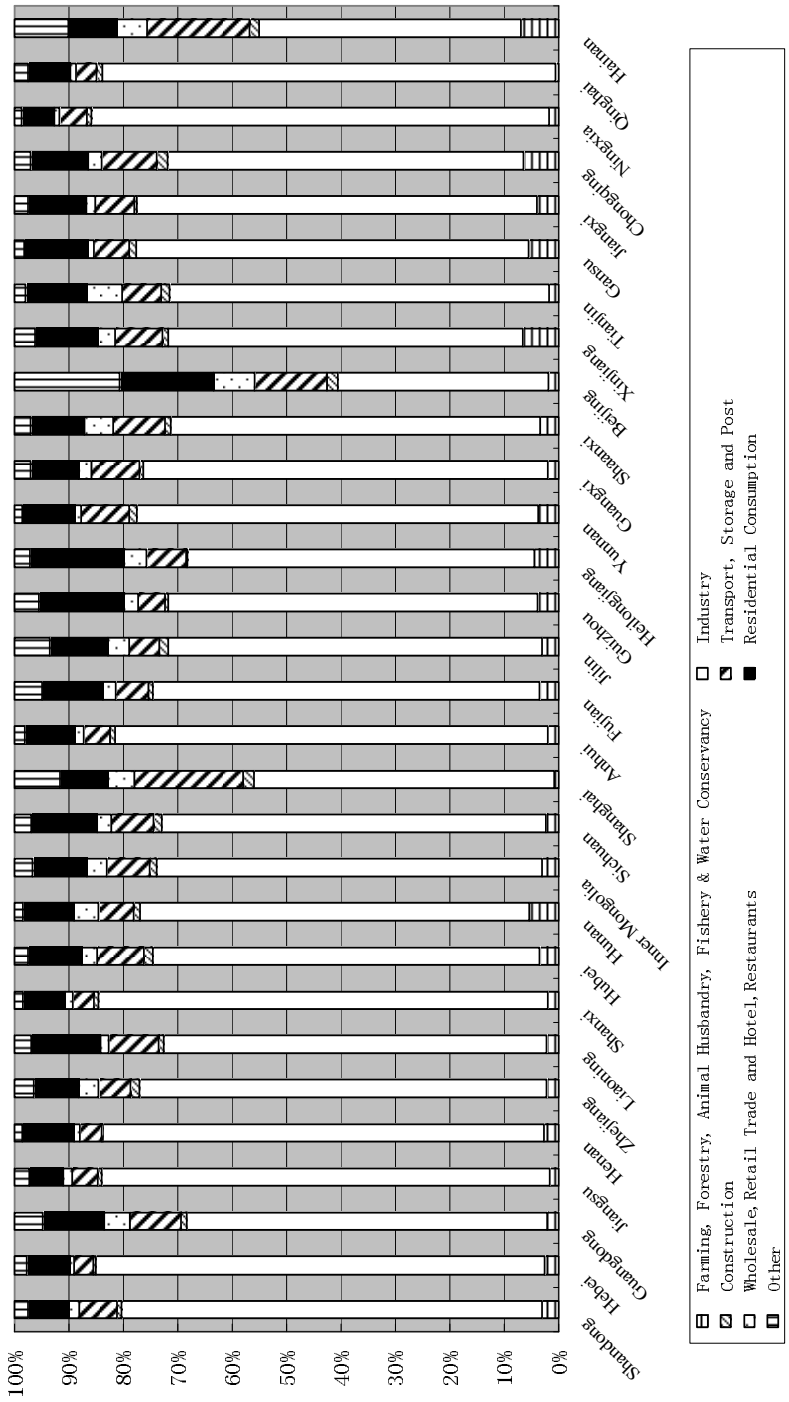

Figure 1 The Composition of Carbon Consumptions