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Regional Low-carbon Level Evaluation from an Industrial Low-carbon Perspective

Shigang Geng[a, b], Weidong Meng*[a], Shaochen Sun[b], Lili Yi[b], Haiyun Qi[b]

[a] Yanshan University, Qinhuangdao 066004, China;
[b] Environmental Management College of China, Qinhuangdao 066004, China.
shuji@ysu.edu.cn

This paper presents two industrial low-carbon evaluation models. One indicates the leading role of characteristic industries in regional low-carbon evaluation, while the other compares regional low-carbon level with the domestic advanced level. Because the data sources of carbon emissions have some limitations, this paper only evaluates industrial low-carbon level in five provinces in 2010, including Hebei, Henan, Heilongjiang, Jiangsu and Shandong. The results of two low-carbon level evaluation models are basically consistent and reasonable.

1. Introduction

With the development of industrial economy of the world, a sharp increase in population, the infinite rise of human desire, and the way of life without control, the climate of the world is becoming much worse: carbon dioxide emissions is increasing, the earth's ozone layer is suffering from an unprecedented crisis, and global catastrophic climate change appeared frequently. All these have brought serious harm to our survival environment and health.

China is a developing country with a large population. China's economy develops slowly, and climate conditions is complex, ecological environment is fragile and quite vulnerable to the adverse effects of climate change. At the same time, China is in the critical period of building a well-off society in an all-round way. China is also in an important stage of the accelerated development of industrialization and urbanization. The task of developing the economy and improving people's livelihood are very arduous, so China is facing more challenges than the developed countries to confront the climate change. China is a big manufacturing country in the world, with a population of 1.3 billion. There is no doubt that China generated most carbon emissions in the world and the international pressure on cutting emissions is increasing.

As a responsible country, the Chinese government has been promoting China's low carbon development. At the World Climate Conference in Copenhagen in December 2009(Liu et al., 2012), the Chinese government set forth a strategic goal that by 2020 it will lower carbon dioxide emissions per unit of GDP by 40% to 45% from the 2005 level(Wang et al., 2014). In July 2015, Premier Li Keqiang proposed, based on the national circumstances, development stage, sustainable development strategy and international responsibility (Svarstada et al., 2008; Glseser et al., 2010), the Chinese government has determined its actions by 2030, namely achieving the peaking of carbon dioxide emissions around 2030 and making best efforts to peak early; and lowering carbon dioxide emissions per unit of GDP by 60% to 65% from the 2005 level. Actually, the national goal of carbon intensity reduction is to reduce carbon dioxide emissions per unit of GDP and develop economy simultaneously(Ma et al., 2013), so as to achieve industrial low-carbon development (Bunning et al., 2014). This paper presents evaluation methods of regional low-carbon level from an industrial low-carbon perspective(Tan et al., 2011).

2. Overview of regional low-carbon evaluation

Weighted method is more frequently used in low-carbon city evaluation. Low-carbon index weight is determined employing such frame models as DPSIR and PSR through AHP and entropy method to analyze the

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urban low-carbon development level(Minoru et al., 2015).

There are slight differences in various low-carbon evaluation index systems(World Resources Institute, 2013). Many scholars (Liu et al., 2015; Li et al., 2014) have chosen the proportion of the secondary industry as a negative index and that of the tertiary industry as a positive one. That is to say, the secondary industry is not conducive to improving the urban low-carbon level, while the tertiary industry plays a positive role. For a country(Wang et al., 2015), industrial structure development should be in line with the DCIS curve of the international industrial structure evolution coefficient. China is at the bottom of the U-shaped curve (Li, 2015; Chiung et al., 2011), so it is imperative to increase the proportion of the tertiary industry. On the other hand, a city boasts distinct industrial characteristics due to its position in the national economic structure(Dincer, 2002). For instance, Qinhuangdao, as an eco-tourism city, owns a high proportion of energy-intensive and high-polluting industries like cement and glass, and there is an urgent need of industrial restructuring to phase out such industries and increase the proportion of low-carbon industries, which is consistent with the development trend of DCIS curve(Jiusto et al., 2008). For another example, Shenyang, as an old industrial base, is one of China’s important equipment industrial bases where the secondary industry is a pillar industry(Chen et al., 2011). Also, Sanya is a famous tropical seashore tourism city and tourism is an industrial characteristic. If the proportion of the secondary and tertiary industries is designated as a major index to measure the urban low-carbon development level(De et al., 2013; Zhou et al., 2015), it will be unfair to cities with different characteristic industries. Furthermore, different cities have different low-carbon levels of the same industry(Japan, 2014). Therefore, regional low-carbon development should attach importance to enhancing the low-carbon level of characteristic industries(Liang et al., 2011; Li et al., 2013).

BAO Chao et al. (Bao et al., 2013; Nicolas et al., 2015; Nina et al., 2014) designated environmental factors like air and water quality as low-carbon index system (Khare et al., 2013; Lehmann et al., 2013). As far as China’s current environmental conditions are concerned, low-carbon level exerts effect on environmental quality rather than environmental quality affects low-carbon level(World, 2013). Environment is not a factor for measuring low-carbon level(Lehmann, 2013), but a manifestation of regional low-carbon level. XIE Wenting & ZHUANG Guiyang et al. (Zhuang et al., 2014; Wang et al., 2016) designated low-carbon policy as an evaluation index of regional low-carbon development level. In fact, low-carbon policy is just a means that may reduce carbon emissions or not, eventually attributed to the change in total carbon emissions(Preva et al., 2010).

3. Industrial low-carbon evaluation system

At present, many parts of China have carried out calculations of carbon emissions inventory, keep statistics of industrial carbon emissions. This paper establishes an evaluation system of regional industrial low-carbon level based on the related research data of carbon emissions.

To avoid losing industrial output in carbon intensity and weight coefficient formulas, carbon emission efficiency (*q/C*) is used. The evaluation formula of industrial low-carbon level can be written as:

$$W = \sum_i (q_i / C_i) \bullet r_i \quad i=1,2,3 \tag{1}$$

where *i* represents the primary, secondary and tertiary industries, q_i represents industrial output, C_i represents corresponding industrial carbon emissions and *r* is weight coefficient. A larger *W* means a higher industrial low-carbon level.

r can be expressed in two forms:

(a) The calculation formula of weight that indicates the leading role of characteristic industries in regional low-carbon evaluation can be expressed as:

$$r_i = q_i / Q \quad i=1,2,3 \tag{2}$$

where *Q* represents regional GNP.

(b) The weight of evaluation that compares regional low-carbon level with the domestic advanced one can be calculated as:

$$r_i = \frac{1}{\max(q_i / C_i)} \quad i=1,2,3 \tag{3}$$

In this paper, data of q_i derives from *China Statistical Yearbook*. Carbon emissions data derives from *Main Energy Consumption of Large-scale Industrial Enterprises* and *Comprehensive Energy Balance Sheet* in some provincial statistic yearbooks. C_i is calculated based on inventory establishing method presented in *IPCC* (IPCC , 2014)*Guidelines for National Greenhouse Gas Inventory* (Zhang et al., 2015) Since data sources of C_i are limited, this paper only makes a comparative analysis of low-carbon development level in Hebei, Henan, Heilongjiang, Jiangsu and Shandong Provinces in 2010 using the above-mentioned formulas (Rong, 2016; Wang et al., 2014; Hong et al., 2015; Guo et al., 2012), and Fig. 1 , Fig. 2, Table 1 and Table 2 show q_i and C_i data of the five provinces.

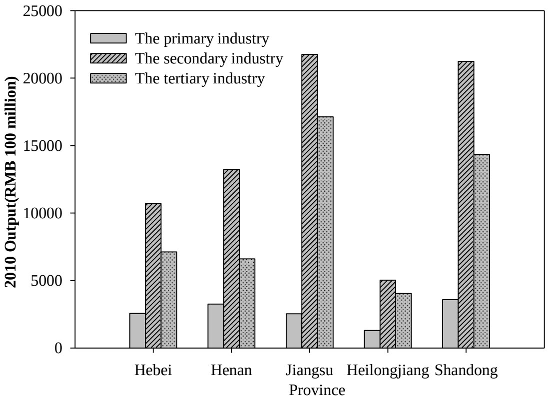

Figure 1: The industrial output of five provinces

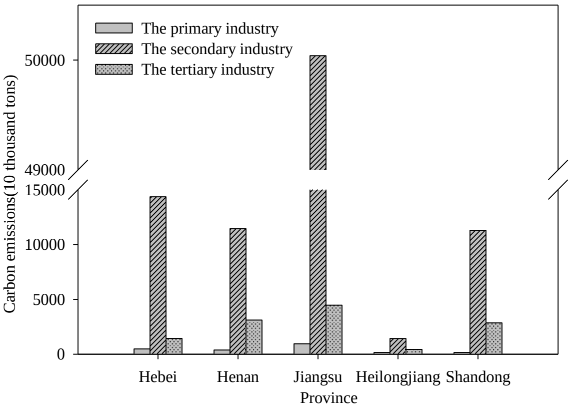

Figure 2: The industrial carbon emissions of five provinces

Table 1: The industrial output of five provinces

		Hebei	Henan	Jiangsu	Heilongjiang	Shandong
Output(RMB 100 million)2010	The primary industry	2563	3258	2540	1303	3588
	The secondary industry	10708	13226	21754	5025	21239
	The tertiary industry	7124	6608	17131	4041	14343

Table 2: The industrial carbon emissions of five provinces

		Hebei	Henan	Jiangsu	Heilongjiang	Shandong
Carbon emissions(10 thousand tons)2010	The primary industry	484	379	945	160	157
	The secondary industry	14337	11430	50039	1429	11287
	The tertiary industry	1439	3111	4466	439	2847

4. Results and analysis

4.1 Results

The industrial low-carbon levels W of five provinces are calculated according to Eq. (1), (2) and (3), as shown in Table 3 and Table 4.

Table 3: The industrial low-carbon levels of five provinces by Eq.(2)

Evaluation method	Index	Hebei	Henan	Jiangsu	Heilongjiang	Shandong
Eq.(2)	W_1	0.67	1.21	0.16	1.02	2.10
	W_2	0.39	0.66	0.23	1.70	1.02
	W_3	1.73	0.61	1.59	3.59	1.84
	W	2.79	2.48	1.98	6.31	4.96
Ranking of low-carbon level		3	4	5	1	2

Table 4: The industrial low-carbon levels of five provinces by Eq.(3)

Evaluation method	Index	Hebei	Henan	Jiangsu	Heilongjiang	Shandong
Eq. (3)	W_1	0.23	0.38	0.12	0.35	1.00
	W_2	0.21	0.33	0.12	1.00	0.54
	W_3	0.54	0.23	0.42	1.00	0.55
	W	0.98	0.94	0.66	2.35	2.08
Ranking of low-carbon level		3	4	5	1	2

Table 3 and Table 4 shows that the results of low-carbon level evaluation using Eq.(2) and (3) are basically consistent. Heilongjiang had the highest industrial low-carbon level in 2010 followed by Shandong and Hebei, while Jiangsu had the lowest level.

4.2 Results analysis

Heilongjiang is the largest grain production base and an important milk production base where the primary industry is comprehensively mechanized. The secondary industrial is large-scale, with the output accounting for 48% of the total output in 2010. Mechanical manufacturing and petrochemical industries play an important role in China with higher scientific and technological content and greater regional advantages. Furthermore, the secondary industry is relatively centralized, mainly in cities like Harbin, Qiqihar and Daqing. Upon a comprehensive comparison, although total output was not large in Heilongjiang, there were a relatively higher economic efficiency and industrial low-carbon level per unit of carbon emission. From the perspective of environmental quality, Heilongjiang is better than other provinces.

With eight efficient industrial belts, such as grain and oil, vegetables and aquatic products Shandong has been ranked among the top in the agricultural industrial competitiveness. In addition, a great number of agricultural production and processing bases has taken shape, with long agricultural industry chain and high value-added farm produce. As a result, Shangdong had the highest primary industrail low-carbon level among the five provinces.

Jiangsu has the highest economic output among the five provinces. But the primary industrial low-carbon level was relatively backward as a result of scattered farmlands and lower-level agricultural mechanization. During the “11th Five-year Plan” period, the value added of new and high technology industries still accounted for a lower proportion of manufacturing industry. The traditional industries like steel, machinery, petrochemicals and nonferrous metals mainly relied on price competition. Compared with international advanced level, its technological level lagged far behind. At the low end of industrial chain, many new and high technology industries were labor-intensive processing and assembling operations. In 2010, the tertiary industrial output accounted for 41% of the total output. Compared with emerging service industries like financial technology and consultation, service industry was mainly traditional with greater environmental damage and more contaminants. During the “12th Five-year Plan” period, industrial structure was gradually optimized, innovation ability was continuously improved and industrial low-carbon level was greatly enhanced.

5. Conclusions

In terms of industrial structure, the secondary industrial output in Heilongjiang accounted for 48% of the provincial total output, while Jiangsu was 53%; the tertiary industrial output value in Heilongjiang accounted for 39% of the provincial total output value, while Jiangsu was 41%. So there were few differences in industrial structures of the two provinces. However, evaluation demonstrated that Heilongjiang had a much higher low-carbon level than Jiangsu. As can be seen from evaluation results, the presented evaluation methods, in line with the national strategy of reducing carbon intensity, helps fine regional characteristic industries as well as enlarge and strengthen leading industries to embark on a road of industrial low-carbon development.

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References

Bao C., Luo K., 2013, Integrated assessment and analysis of the low-carbon development levels for Chinese provincial capital cities, Journal of University of Chinese Academy of Sciences, 30, 497-503 (in Chinese).
Bunning J., 2014, Governance for regenerative and decarbonised eco-city regions, Renewable Energy, 67, 173-179.
Chen X.D., Xi F.M., Geng Y., Fu J.T., 2011, The potential environmental gains from recycling waste plastics: simulation of transferring recycling and recoveryn technologies to Shenyang. Waste Manage, 31, 168-179.
Crouse K.B., 2011, Cities addressing climate change: Introducing a tripartite model for sustainable partnership, Sustainable Cities and Society, 1, 227–235.
De J.M., Wang D., Yu C., 2013, Exploring the relevance of the eco-city concept in China: the case of Shenzhen Sino-Dutch low carbon city, Journal of Urban Technology, 20, 95-113.
Dincer I., 2002, Technical, Environmental and exergetic aspects of hydrogen energy systems. International Journal of Hydrogen Energy, 27, 265-285.
Dong L., Fujita T., Zhang H., Dai M., Fujii M., Ohnishi S., Geng Y., Liu Z., 2013, Promoting low-carbon city through industrial symbiosis: A case in China by applying HPIMO model, Energy Policy, 61, 864-873.
Fujii M., Fujita T., Dong L, Lu C.P., Geng Y., Behera S.K., Park H.S., Chiu A.S.F., 2015, Possibility of developing low-carbon industries through urban symbiosis in Asian cities, Journal of Cleaner Production, 4, 1-11.
Glseser E., Kahn M., 2010, The greenness of cities: Carbon dioxide emissions and urban development, Journal of Urban Economics, 67, 404-418.
Guo C.X., 2012, Effect of industrial structure change on carbon emission in China, China Population, Resources and Environment, 22, 15-22 (in Chinese).
Hong Y.Y., 2015, Study on carbon emissions of industry structure and energy structure changes: an empirical test by using Environmental Kuznet Curve, Environmental Science &Technology, 38, 266-272.
Hsua C.W., Chang P.L., Hsiung C.M., 2011, Construction and application of a performance assessment model for energy conservation and carbon reduction industries, International Journal of Hydrogen Energy, 36, 14093-14102.
IPCC, 2014, Climate change 2014: mitigation of climate change. In: Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A.,Baum, I., Brunner, S., Eickemeier, P., Kriemann, B., Savolainen, J., Schl€ omer, S.,von Stechow, C., Zwickel, T., Minx, J.C. (Eds.), Contribution of Working Group III to the fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Japan Containers and Packaging Recycling Association, 2014, Puraschikku-sei yoki hoso ni kakawaru jissyo shaken (Substantiative experiment related to plastic containers and packaging) (in Japanese).
Jiusto S., 2008, An indicator framework for assessing US state carbon emissions reduction efforts (with baseline trendsfrom 1990 to 2001), Energy Policy, 36, 2234-2252.
Khanna N., Fridley D., Hong L.X., 2014, China’s pilot low-carbon city initiative: A comparative assessment of national goals and local plans, Sustainable Cities and Society, 11, 110-121.
Lehmann, 2013, Low-to-no carbon city: Lessons from western urban projects for the rapid transformation of Shanghai, Habitat International, 37, 61-69.
Li X.S., Li X.Y., Wang D.R., 2014, Study on low-carbon economic evaluation of Hebei Province based on DPSIR Model, Journal of Hebei University of Economics and Business, 35, 106-109 (in Chinese).
Liu J., Wang R., Sun Y.W., 2012, Analysis of development path for low-carbon pilot provinces in China, China Population Resources and Environment, 03, 56-62.
Liu L.H., 2015, Calculation and analysis of the city low-carbon developmental index based on DPSIR model: taking the urban district of Jiangmen City as an example, Environmental Science & Technology, 38, 273-278 (in Chinese).
Li Z.W., 2015, Research on the coordinated development of industrial structure and employment structure in Beijing-Tianjin-Hebei, Journal of Tangshan Normal University, 37, 145-148 (in Chinese).
Ma D., Chen W.Y., 2013, Development status of low- carbon in Shanghai, China Population Resources and Environment, 23, 26-32.

Mat N., Cerceau J., Shi L., Park H.S., Junqua G., 2015, Socio-ecological transitions toward low-carbon port cities: trends, changes and adaptation processes in Asia and Europe, Journal of Cleaner Production, 12, 1-14.

Preval N., Chapman R., Pierse N., Howden-Chapman P., 2010, Evaluating energy, health and carbon co-benefits from improved domestic space heating: arandomised community trial, Energy Policy, 38, 3965-3972.

Rong R., 2016, A study on scenario predication for industrial carbon emissions and emission reduction strategies in Shandong Province, Sino-Global Energy, 21, 94-98 (in Chinese).

Svarstada H., Petersenb L.K., Rothmanc D., 2008, Discursive biases of the environmental research framework DPSIR, Land Use Policy, 1, 116-125.

Tan F., 2011, Low-carbon city planning: Exploration of China low-carbon cities development, Environmental Economy, 6, 68-69.

Wang S.H., Yu W.Y., Zhang W., 2014, The scenario analysis of low- carbon based on improved IPAT model in China, Ecological Economy, 30, 19-23.

Wang W.L., Huang X.J., 2015, Decompositions model of factors and substantiation analysis of area carbon dioxide emissions intensity change, Ecological Economy, 54, 19-25(in China).

Wang F., Fu L.F., Liu R.Y., Liu J., Wu C.X., 2016, Combined evaluation on the level of city low-carbon development: taking 13 cities in Jiangsu Province as examples, Ecological Economy, 32, 46-50 (in Chinese).

Wang X.N., Wang Y.X., Duan H.Y., Sun N.Y., 2014, Forecasting areas carbon emissions of energy consumption and controllability study, China Population, Resources and Environment, 24, 9-15 (in Chinese).

World Resources Institute, 2013, New greenhouse gas accounting tool will help China's cities pursue low-carbon development, Retrieved from World Resources Institute: http://www.wri.org/blog/new-greenhouse-gas-accounting-tool-will-help-china%E2%80%99s-cities-pursue-low-carbon-development.

Yang L., Brown C., 2011, Assessing the co-benefits of greenhouse gas reduction: health benefits of particulate matter related inspection and main-tenance programs in Bangkok, Thailand. Science of The Total Environment, 409, 1774-1785.

Zhang X.M., Zhuang G.Y., 2015, A study on city greenhouse gases inventory development towards for practical application, Ecological Economy, 31, 21-25 (in Chinese).

Zhou N., He G., Williams C., 2015, ELITE cities: a low- carbon eco-city evaluation tool for China, Ecological Indicators, 48, 448-456.

Zhuang G.Y., Zhu S.X., Yuan L., Tan X.J., 2014, Rangking of low-carbon development level of Chinese cities and internation an comparative study, Journal of China University of Geosciences (Social Sciences Edition), 14, 17-24 (in Chinese).