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Evaluation of Low-carbon Economy Development Level in Harbin

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Abstract. To build a low-carbon economic evaluation system that includes four criteria layers including economic level, energy consumption, social development and environmental quality, and selected 18 evaluation indicators, and calculate the comprehensive evaluation value of low-carbon economy in Harbin based on the combined AHP-entropy method. And compared with the national and low-carbon pilot city of Xi'an, evaluate the low-carbon economic development level of Harbin City. The results show: in 2013-2016, the low-carbon economy level of Harbin was slightly higher than the national average and Xi'an. Through the analysis of the standard layer, in order to improve the low-carbon economic development in Harbin, economic development, energy consumption and social development should be improved, and the environmental quality should be greatly improved.

1. Introduction

At present, the contradiction between economic development and ecological environment protection has become increasingly prominent. Although the rapid economic development has brought people a convenient and prosperous living environment, it has also caused series of problems, such as global warming, shortage of resources and the destruction of carbon balance of the eco-system, restricted the development of people. Therefore, in order to create a better living environment and improve the prominent contradiction between economic development and ecological environment protection, the UK put forward the term “low-carbon economy” in the 2003 government document [1]. The low-carbon economy means under the guidance of the concept of sustainable development, through technological innovation, institutional innovation, industrial transformation, new energy development and other means, as much as possible to reduce coal, oil and other high-carbon energy consumption, reduce greenhouse gas emissions, to achieve Economic and social development and ecological environment protection a win-win economic development form [2]. In 2015, nearly 200 parties reached《The Paris Agreement》to cope with the global climate change issue [3]. China, as a contracting party, promised to achieve a 40-45% reduction in carbon intensity by 2020. In 2010, China initiated the pilot work of the first batch of national low-carbon provinces and low-carbon cities (five provinces and eight cities). In 2012, 29 cities were identified to carry out the second batch of national pilot projects for low-carbon provinces and low-carbon cities.

Domestic and foreign scholars respectively study the low-carbon economy from the aspects of the connotation of low-carbon economy, the construction of a low-carbon economic development level evaluation system, the evaluation of low-carbon economic development level, and the development of low-carbon economic development programs. Koji Shimada et al developed a low-carbon economic development plan that can be applied locally for a long period of time and applied it to Shiga Prefecture in Japan to provide a direction for the development of a low-carbon economy [4]. Yang Dezhi constructed a low carbon city evaluation system including four systems of economic development, low carbon technology, low carbon environment and low carbon society, and used the principal component analysis to measure the low carbon economic development level of Shanghai in 2000-2009 years [5]. Based on the data of 2008-2011 years in 15 cities and cities in the Central Plains Economic Zone, Zhou Zejiong used the Super-SBM model considering unexpected output to carry out an empirical study on its low carbon economy, and analysed the projection of its production frontiers and the dynamic changes of low carbon economic development performance [6]. Xie Zhejiang [7], Duan Yongfeng et al [8] all use the DEA model to evaluate the development of low-carbon economy in provinces and cities. Zhang [9], Zhang Xiao fang [10], Liu [11], and Yu Yang [12] respectively. Analysed the status of low-carbon economic development in Jiangxi, Gansu, Zunyi and Daxinganling At present, domestic researches on low-carbon economy are mostly large-scale analyses. Most scholars stand at the national level to analyse the overall level of China's low-carbon economy. However, because of the vast territory, the large span of the East and the west, the uneven distribution of resources and the obvious difference of economic development, the current situation of low carbon development in China can only be used as a reference for the development of low carbon economy in various provinces and cities, and cannot replace the development status of a certain area. In addition, many scholars have already conducted studies on low-carbon economic levels for specific provinces and cities, but they are limited to pilot cities of low-carbon economy initiated in 2010 and 2012, and their research results are not universal. To sum up, in view of the large area and large population of Harbin, the heating period is up to more than 180 days in the high and cold regions, and the heating mode is mainly based on coal burning, and there is no corresponding research results for the development of low carbon economic level. In view of this, this paper takes Harbin, a relatively low-carbon economic development research area as the research object, construct a low-carbon economic evaluation system and use AHP-entropy weight method to evaluate the development level of low-carbon economy in Harbin from 2011 to 2016, and compare it with the national average and low-carbon pilot city Xi’an to analyse the development advantages and disadvantages of low-carbon economy in Harbin, and put forward some proposals.

2. Construction of Low-carbon Economic Evaluation Index System in Harbin

2.1. Evaluation System Construction

Low-carbon economy is closely related to economic development, energy consumption, social development and environmental quality. Assessing the development level of a low-carbon economy in a region or city mainly depends on the level of development in these four areas. Therefore, this study established a low-carbon economic evaluation system that taking economic development, energy consumption, social development and environmental quality as the standard layers and selected the corresponding indicators from four aspects to evaluate the development level of low-carbon economy in Harbin. Since the four standard layers related to low carbon economy still involve a large number of evaluation indicators, this study adopted the comprehensive method and analysis method [13] for the primary selection of evaluation indicators, referring to the theoretical research achievements of the scholars on Zheng Linchang, [14], Ma Jun [15], Xin Ling [16] and Feng Zhanmin [17] on the development of low carbon economy, and practical application cases of Jiangxi [18], Hubei [19, 20], Taiyuan [21] and Shandong [22] etc, selected 26 low carbon economic evaluation indexes from these four aspects. The specific indicators are shown in Table 1.

In order to select the evaluation indexes which have high correlation with low carbon economy and reduce the workload of the evaluation, 26 evaluation indexes need to be screened. In this study, AHP-

Entropy weighting method [23], which combines subjective and objective weights, is used to calculate index weights to ensure the objectivity and representativeness of the evaluation index.

Table 1. Evaluation index of low carbon economic development level in Harbin (primary election)

arget layer	Standard layer	Index layer	Unit	Index direction	Combined weight	Weight sort
The Low-carbon Economic Development Level in Harbin	Economic level	Per capita GDP	yuan/p	Positive	0.07002	4
		The proportion of primary industry in GDP	%	Negative	0.02272	19
		The proportion of Secondary industry in GDP	%	Negative	0.02454	16
		The proportion of Tertiary industry in GDP	%	Positive	0.04344	9
		The proportion of fixed assets investment in GDP	%	Positive	0.01648	24
		The proportion of Total retail sales of consumer goods in GDP	%	Positive	0.02410	17
	Energy consumption	Carbon emission intensity	tCO_2/10 k yuan	Negative	0.07203	3
		Per capita energy consumption	kgce/ p.	Negative	0.02467	15
		Unit GDP energy consumption	tce/10 k yuan	Negative	0.15672	1
		The proportion of coal in total energy consumption	%	Negative	0.04618	7
		Per capita water consumption	m^3/p	Negative	0.02502	12
		Per capita electricity consumption	kw·h/p	Negative	0.01860	21
	Social development	Natural population growth rate	‰	Negative	0.04552	8
		Population density	p/km^2	Negative	0.07245	2
		Urban-rural Engel coefficient gap	%	Negative	0.02548	14
		Million people own buses	cars	Positive	0.02278	18
		Centralized heating penetration rate	%	Positive	0.01599	25
		The proportion of R&D in GDP	%	Positive	0.01235	26
		Urban registered unemployment rate	%	Negative	0.01734	22
		Urbanization rate	%	Positive	0.02639	13
	Environmental Quality	Environmental air quality standard rate	%	Positive	0.05942	5
		Urban sewage centralized treatment rate	%	Positive	0.02912	11
		Harmless treatment rate of urban garbage	%	Positive	0.01717	23
		Environmental noise equivalent sound level	dB (A)	Negative	0.02216	20
		Forest cover rate	%	Positive	0.05924	6
		Per capita possession of public green area	m^2/p	Positive	0.03006	10

2.2. Calculation of indicator weights

2.2.1. AHP weight calculation. (1) Use the 1-9 scale method to score the importance of the indicators under each standard layer, construct a judgment matrix. The scale and meaning of the judgment matrix are shown in the Table 2.

Table 2. The scale and meaning of the judgment matrix

Importance	Equally	A little more	Obviously	Strongly	Extremely	A little less	Obviously not	Strongly not	Extremely not
Assignment	1	3	5	7	9	1/3	1/5	1/7	1/9

According to the assignment of Table 2, a dimensionless reciprocal matrix B can be constructed.

$$B=\begin{bmatrix} b_{11} & \Lambda & b_{1n} \\ \mathrm{M} & & \mathrm{M} \\ b_{n1} & \Lambda & b_{nn} \end{bmatrix} \tag{1}$$

(2) The weight calculation process is as follows

$$M_i=\prod_{j=1}^{n} b_{ij} \quad \text{(i=1, 2…n)} \tag{2}$$

$$\overline{W_i}=\sqrt[n]{M_i} \tag{3}$$

$$W_i^{(a)}=\overline{W_i}\Big/\sum_{j=1}^{m}\overline{W_j} \tag{4}$$

Then $w^{(a)} = [w_1 \text{ (a)}, w_2 \text{ (a)}\dots w_m \text{ (a)}]^T$ is the desired feature vector, which is the weight vector. $W_i^{(a)}$ is the weight of the indicator Bi relative to a determined by the AHP method.

(3) In order to ensure the consistency of the judgement matrix, the consistency matrix of the constructed judgement matrix should be checked.

2.2.2. Entropy weight calculation. (1) Index dimensionless

Positive index dimensionless

$$a_{ij}=\begin{cases} 1 & ; \quad x_{ij}=\max\limits_{1\le i\le m} x_{ij} \\ \dfrac{x_{ij}-\min\limits_{1\le i\le m} x_{ij}}{\max\limits_{1\le i\le m} x_{ij}-\min\limits_{1\le i\le m} x_{ij}} & ; \min\limits_{1\le i\le m} x_{ij}<x_{ij}<\max\limits_{1\le i\le m} x_{ij} \\ 0 & ; \quad x_{ij}=\min\limits_{1\le i\le m} x_{ij} \end{cases} \tag{5}$$

Negative index dimensionless

$$a_{ij}=\begin{cases} 1 & ; \quad x_{ij}=\min\limits_{1\le i\le m} x_{ij} \\ \dfrac{\max\limits_{1\le i\le m} x_{ij}-x_{ij}}{\max\limits_{1\le i\le m} x_{ij}-\min\limits_{1\le i\le m} x_{ij}} & ; \quad \min\limits_{1\le i\le m} x_{ij}<x_{ij}<\max\limits_{1\le i\le m} x_{ij} \\ 0 & ; \quad x_{ij}=\max\limits_{1\le i\le m} x_{ij} \end{cases} \tag{6}$$

(2) Use the power coefficient method to correct aij, and finally ensure that each operation data is greater than 0, which is easy to take logarithm.

$$y_{ij} = 0.6 \times a_{ij} + 0.4 \quad (7)$$

(3) The weight calculation process is as follows

$$p_{ij} = y_{ij} \Big/ \sum_{j=1}^{n} y_{ij} \quad (8)$$

$$e_i = -k \sum_{j=1}^{n} p_{ij} \cdot \ln p_{ij} \text{ ; (k=1/lnn)} \quad (9)$$

$$\partial_i = 1 - e_i; (i = 1,2,\ldots,m) \quad (10)$$

$$w_i^{(e)} = \partial_i \Big/ \sum_{i=1}^{m} \partial_i; (i = 1,2,\ldots,m) \quad (11)$$

Table 3. Evaluation index of screening and data value of 2011-2016

Index layer	Region	2011	2012	2013	2014	2015	2016
Per capita GDP	Harbin	42736	45810	50498	53872	59027	63445
	National	36403	40007	43852	47203	50251	53980
	Xi'an	45561	51499	57464	63794	66938	71647
The proportion of Secondary industry in GDP	Harbin	38.8	36	34.8	33.4	32.4	31.1
	National	52	49.9	48.5	47.8	42.4	37.4
	Xi'an	40.91	40.53	40.59	39.96	36.65	35.02
The proportion of Tertiary industry in GDP	Harbin	50.7	52.9	53.5	54.9	55.9	57.6
	National	43.8	44.9	47.2	47.5	52.9	58.2
	Xi'an	54.61	55.02	55.34	56.13	59.55	61.29
The proportion of Total retail sales of consumer goods in GDP	Harbin	48.8	52.63	54.38	57.51	59.02	61.36
	National	37.59	38.92	40.8	42.22	43.67	44.69
	Xi'an	52.7	54.63	55.69	56.33	58.7	59.38
Carbon emission intensity	Harbin	1.455	1.391	1.255	1.151	1.051	1.087
	National	1.9722	1.8555	1.7463	1.6486	1.5556	1.4619
	Xi'an	0.4515	0.4066	0.4649	0.3612	0.2996	0.2808
Per capita energy consumption	Harbin	2492.44	2554.73	2536.66	2497.34	2520.85	2765.43
	National	2872.24	2969.91	3063.91	3113.03	3127.45	3153.23
	Xi'an	1643.59	1779.18	2128.47	1809.48	1403.91	1371.7
Unit GDP energy consumption	Harbin	0.583	0.558	0.503	0.462	0.421	0.436
	National	0.86	0.82	0.79	0.75	0.71	0.68
	Xi'an	0.555	0.535	0.516	0.486	0.41	0.394
The proportion of coal in total energy consumption	Harbin	74.46	74.71	74.33	79.6	78.87	73.63
	National	70.2	68.5	67.4	65.6	63.7	62
	Xi'an	59.18	54.13	61.26	66.57	75.27	74.56
Per capita water consumption	Harbin	38.02	35.1	36.58	33.15	20.78	21.39
	National	58.77	53.96	55.26	56.18	57.92	59.59
	Xi'an	50.61	60.8	58.82	62.97	66.39	67.75

*Because of the limited space, the data are not enumerated

2.2.3. AHP-entropy weight calculation. Assume that w_i is the final weight of the i-th indicator after the combination of the AHP-entropy weight method, and denotes w_i as a linear combination of $wi^{(a)}$ and $wi^{(e)}$ (i=1,2,…,m), that is:

$$w_i = 0.5w_i^{(a)} + 0.5w_i^{(e)} \tag{12}$$

Through calculations, the weight values of the 26 evaluation indicators are shown in Table 3, and the indicators with the weight values ranked in the top 18 are selected to construct the Harbin low-carbon economic evaluation system. The main sources of data are Harbin Statistical Yearbook and National Economic and Statistics Bulletin of the National Economic and Social Development of Harbin. The specific data are shown in Table 3.

2.3. Calculation of Comprehensive Evaluation Value of Low-carbon Economy

Use S_j to indicate the comprehensive evaluation results of low-carbon economy:

$$S_j = \sum_{i=1}^{m} y_{ij} w_i \tag{13}$$

In the formula: yij —— dimensionless index value;

wi —— the final weight of the i-th indicator after the combination of the AHP-entropy weight method

Sj —— Comprehensive evaluation of the j-th sample. Since yij is a positive indicator, the greater the value of Sj, the better the evaluation of low-carbon economy.

3. Evaluation of Low-carbon Economy Development Level in Harbin

In order to better evaluate the low-carbon economy development level in Harbin, this study taking the national low carbon economy development level as the average value, taking the low carbon economic development level of Xi'an, a pilot city of low carbon economy, as the reference value, selects the same evaluation index and calculation method to calculate the comprehensive evaluation value of the low carbon economy of the whole country and Xi'an city, and through comparative analysis, determine the overall development of low-carbon economy in Harbin. At the same time, through comparative analysis of various subsystems, we evaluated the low-carbon economic development level of Harbin from four aspects of economic development, energy consumption, social development, and environmental quality, and analyzed the advantages and disadvantages of Harbin's low-carbon economic development, and proposed corresponding Suggestions and opinions.

3.1. Subsystem analysis

The comparison of the four subsystems' comprehensive evaluation values with that of the whole country and Xi'an is shown in Fig. 1- Fig. 4.

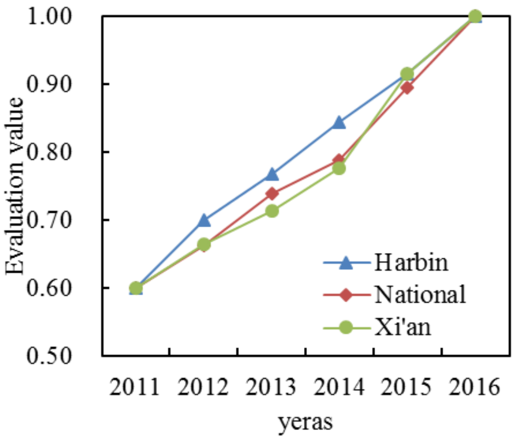

Figure 1. Economic development comprehensive evaluation value

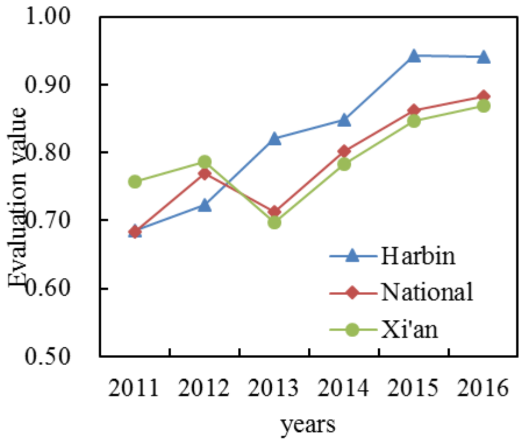

Figure 2. Energy consumption comprehensive evaluation value

From Figure 1, it can be seen that the economic development level of Harbin is increasing year by year. The comprehensive evaluation value of economic development are higher than that of Xi'an and the national average except that in 2015. In terms of the 4 evaluation indicators under the economic development subsystem, in 2016, the regional GDP of Harbin City was 610.16 billion yuan, accounting for only 0.82% of the GDP. The per capita GDP increased from 42, 763 yuan in 2011 to 63,454 Yuan in 2016, higher than the domestic GDP per capita (36,403 - 53,980 yuan), lower than the per capita GDP of Xi'an (45,561 - 71,647 yuan). Harbin's economic development mainly consists of tertiary industries, and the proportion of the output value of the tertiary industry in GDP is increasing year by year, all over 50%. This index is better than the national average (43.8%-58.2%), lower than Xi'an (54.61%-61.29%); the proportion of the output value of the second industry in GDP is decreasing year by year, and it has fallen to 31.1% in 2016. The proportion of the previous year has been lower than that of Xi'an and the national average. The index is relatively excellent, thus it can be seen that Harbin is low in GDP, but the industrial structure is optimized year by year, better than the average level in Xi'an and the country, which is also one of the reasons for the high comprehensive evaluation of the economic development of Harbin. From the domestic consumption demand, the proportion of the total retail sales of consumer goods in Harbin exceeded 60% in 2016, from 48.8% in 2011 to 61.36% in 2016. The growth rate reached 25.7%, and the consumption demand was obviously improved. This index was better than the national average (37.59%-44.69%) and Xi'an (52.7%-59.38%). Therefore, the better industrial structure and higher consumption demand make the economic development level of Harbin have a higher comprehensive evaluation value.

According to figure 2, the energy consumption level of Harbin is increasing year by year. The comprehensive evaluation value of energy consumption rises from 0.685 in 2011 to 0.941 in 2016, increasing 37.4%. The comprehensive evaluation of energy consumption in 2011-2012 years is lower than that of Xi'an and the national average. The average value of energy consumption in the 2013-2016 year is higher than that of Xi'an and the national average. For the 5 evaluation indicators under the energy consumption subsystem, carbon emission intensity is the most direct response of a city's low carbon economy. The carbon emission intensity of Harbin is declining year by year, down from 1.455tCO2/ 10k yuan in 2011 to 1.087tCO2/ 10k yuan in 2011, decreasing 25.3%. Although the carbon emission intensity of Harbin is lower than the national average level, it is about 3-5 times that of Xi'an. Thus, it can be seen that Harbin is gradually developing the low carbon economic development model. However, the carbon emission intensity is still high, and the development of low carbon economy is still in the initial stage of exploration. The per capita energy consumption in Harbin is increasing year by year, this index is superior to the national average, lower than that of Xi'an; the unit GDP energy consumption is declining year by year, this index is obviously superior to the national average level, slightly better than that of Xi'an. It can be seen that although energy consumption in Harbin has increased year by year, and the proportion of coal in energy consumption has remained high, in recent years, the degree of energy use in economic activities has gradually tended to be good, making the comprehensive evaluation of energy consumption in Harbin is slightly higher than that of Xi'an and the national average. The water consumption per capita in Harbin is decreasing year by year, and it is lower than that of Xi'an and the national average. Therefore, Harbin has a high advantage in the use of water resources.

As can be seen from Figure 3, the level of social development in Harbin is obviously rising, and the comprehensive evaluation value of social development has risen from 0.609 in 2011 to 0.904 in 2016, increasing 48.4%. The comprehensive evaluation of social development in 2011-2013 years is lower than that of Xi'an and the national average, and that in 2014-2016 years is higher than that of Xi'an and the national average. In terms of the 5 evaluation indicators under the social development subsystem, the natural population growth rate of Harbin as a whole showed a declining trend, and it is significantly lower than Xi'an and the national average, and it was negative in 2013 and 2015. The population density of the city was less than 200 p/km2, about 1/4 of the population density of Xi'an, 1/10 of the national average population density. Low natural growth rate and low population density are one of the advantages of low carbon economic development in Harbin, and making the comprehensive evaluation of Harbin's social development for 2014-2016 higher than that of Xi'an and the national average. The Engel coefficient gap in urban and rural areas in Harbin is slightly lower, but it is obviously higher than that in Xi'an and the national average, and the urbanization rate is basically unchanged, and it is obviously lower than that in Xi'an and the national average. Thus it can be seen that the economic development gap between the rural and urban areas in Harbin is large and the level of urbanization is in the backward stage, which is not conducive to low-carbon economy development. According to field survey data, Harbin's current transportation methods are based on ground public transport, with a share rate of about 43%. The quantity of tens of thousands people who own buses is 11.4-13.4 cars, which basically meet the national requirements of the National Civilized City Class A evaluation standard-12 cars, but it is still slightly lower than Xi'an (13.9-15.1 cars) and the national average (11.81-13.84 cars), so the development of the public transport system in Harbin basically meets the urban demand, but the development space is still relatively large, and the urban infrastructure Construction still needs to be improved.

Figure 4 shows that there is a slight upward trend in the environmental quality level of Harbin, and the comprehensive valuation value of environmental quality has increased from 0.774 in 2011 to 0.876 in 2016, an increase of only 13.2%, and the comprehensive evaluation value of environmental quality is higher than the national average and Xi'an in 2011-2012 years, while the 2013-2016 years is obviously lower than the national average and Xi'an. From the 4 evaluation indexes of the environmental quality subsystem, the annual mean value of particulate started to statistics since 2013, the environmental air quality standard rate in Harbin has shown a slight upward trend, and it is obviously better than that in Xi'an, slightly worse than the national average. From the monthly mean value report of atmospheric pollutants in Harbin in 2016, the pollutant concentration was U-shaped, and the concentration in heating period was significantly higher than that in non-heating period. Heating in Harbin is mainly based on coal burning, and the heating period is as long as 180 days. Therefore, the main contributor to atmospheric pollutants is coal in winter. The urban sewage centralized treatment rate in Harbin exceeded 90% in 2016, the level of the previous year was significantly higher than the national average, slightly lower than Xi'an. The urban sewage centralized treatment rate reflects the supporting degree of a local sewage collection and disposal facilities and the compensation for environmental pollution caused by human activities. Therefore, the sewage treatment work in Harbin has been obviously improved, but the development space is still large. Forests and green areas are the main ways to reduce carbon emissions. The per capita possession of public green area in Harbin is kept in 9-10.5m2/ p, there has been a slight decline since 2014, and the overall level is slightly lower than the national average and Xi'an. It can be seen that there is still much space for development in the construction of forests and greenbelts in Harbin.

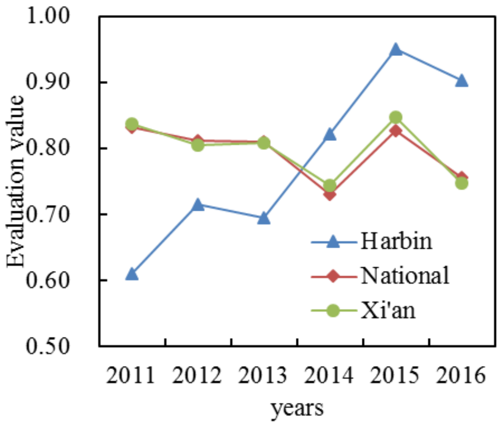

Figure 3. Social development comprehensive evaluation value

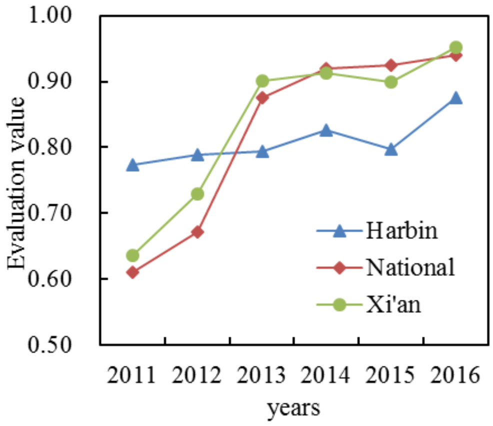

Figure 4. Environmental quality comprehensive evaluation value

3.2. Overall analysis

The comprehensive evaluation of low-carbon economy in Harbin, China and Xi'an is shown in Figure 5.

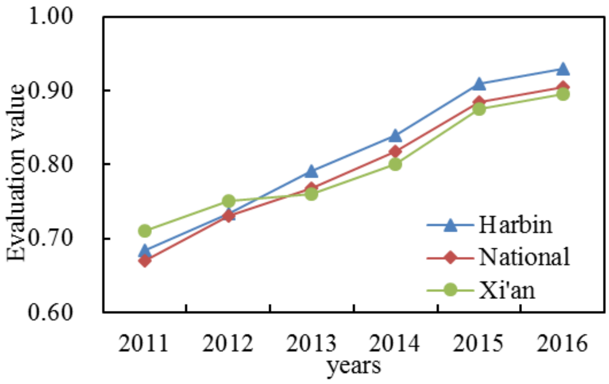

Figure 5. Low-carbon economy comprehensive evaluation value

As can be seen from Figure 5, the level of low-carbon economy development in Harbin City has been rising year by year from 2011 to 2016, which has increased from 0.684 in 2011 to 0.929 in 2016, representing an increase of 35.8%. In 2011 and 2012, Harbin's low-carbon economy was lower than Xi'an, which was higher than the national average, and was higher than the national average and Xi'an in 2013-2016. Therefore, the development of low-carbon economy in Harbin is at the middle and upper levels. Combining with the subsystem analysis results, after 2013, besides the lower level of environmental quality than that of the entire country and Xi'an, Harbin's economic development, energy consumption, and social development are better than those in China and Xi'an. Therefore, Harbin's relatively better low-carbon economic development is due to a better level of economic development, energy consumption and social development, but there is still room for improvement.

4. Conclusion and discussion

The paper constructed a low-carbon economy evaluation index system and compared Harbin's low-carbon economy level with the national average and Xi'an, revealing the strengths and weaknesses of Harbin's development of low-carbon economy. The following conclusions were reached:

(1) The level of low-carbon economy in Harbin is increasing year by year, and is slightly higher than that in the national and Xi'an. The comprehensive evaluation values of the subsystems of

economic development, energy consumption, and social development are increasing year by year, while the comprehensive evaluation value of environmental quality subsystems has declined.

(2) In view of the advantages and disadvantages of low-carbon economic development in Harbin, the future should be optimized in terms of regional GDP, carbon intensity, total energy consumption, urbanization process, and environmental quality. The development level of low carbon economy in Harbin will be greatly improved in the future because of the advantages of local resources, positive policies and the support of national funds.

(3) It is necessary and inevitable for Harbin to develop a low-carbon economy. Harbin should combine the development of low carbon economy with the ecological environment construction. From the reality, we should recognize its own shortcomings and advantages, give full play to the local advantages, do not violate the development stage, step by step, adapt to local conditions, and promote the healthy and sustainable development of the economy and society and the all-round development of people.

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