E3 Journal of Business Management and Economics Vol. 4(10). pp. 206-213, October, 2013
Available online http://www.e3journals.org
ISSN 2141-7482 © E3 Journals 2013

*Full length research paper*

# The research of low-carbon industrial cluster in China based on location quotient method

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Accepted 27 September, 2013

**This article aimed to research the spatial distribution and operation conditions of the recent low-carbon industrial clusters in China and make suggestions for future development. Location quotient method was used to identify industrial cluster. With this method, the article calculated the location quotients about the quantity of companies and the sales revenues, based on a sample of 138 quoted low-carbon corporations from 24 provinces in China. The conclusion showed that the low-carbon industrial clusters mainly located in the developed cities from 13 provinces in the northeast, central part and the southeast of China. Besides, the sales revenue of the low-carbon industry increased steadily in the past five years, while the profit rate, coupled with its proportion in the national economy as a whole, dropped gradually.**

**Keywords:** Low-carbon industry, industrial cluster, location quotient

## INTRODUCTION

With the aggravation of climate change and energy shortage, the low-carbon economy was raised by the British government in 2003 and gets high attention from other countries ( Liaoqin, 2010 ). Some developed countries have put forward “green competitiveness” and set up green trade barrier to restrict the importation of the commodities with high energy consumption and high emission ( Yueping, 2008 ). Therefore, low-carbon economy is an irresistible trend worldwide. Except for the international competition, domestic environmental problems and economic issues in China also call for the development of a low-carbon economy. Chinese energy mainly consists of fossil energy, which has resulted in the high emission of greenhouse gas and subsequent pollution ( Kaihao, 2010).

In this case, China has devoted itself to developing a low-carbon economy. But as Kaihao (2010) reveals, there still exist several crucial problems in the development of a low-carbon industry. On one hand, the low-carbon industry is less competitive and takes less weight in the national economy than the heavy chemical industry.

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On the other hand, domestic low-carbon technology highly relies on import, which increases technical costs and hinders the improvement of the low-carbon industry. Thus, how to scale up low-carbon industry and improve independent research capacity as well as strengthen the competitiveness of low-carbon companies, have become significant issues for Chinese economy.

Industry cluster, as a creative regional organization mode, is one of the highly influential solutions. From the perspective of ensemble, clusters as a whole can achieve external expansion with the advantage of transaction cost, innovation ability and cluster brand. From the perspective of individual, companies in the cluster can intensify their vitality by cooperating and competing with each other (Xiaomeng, 2011). Many industries have established clusters which turn out to be accelerated development. For instance, Xuchao and Jianyu (2012) measured the marine industry clusters and concluded that these clusters had stimulated the progress of China’s Bohai Sea Economic Zone. Bin (2012) indicated that the proportion of industrial clusters in the whole industrial economy in Liaoning Province had increased from 31% in 2009 to 46% in 2011, and their sales revenue accounts for about 50% of the industrial economy in this province in 2012. Therefore, it is reasonable and considerable to apply industrial cluster in low-carbon economy.

However, there is little researche on low-carbon industrial clusters because it has still been a short time since the low-carbon economy was put forward in 2003 (Dandan, 2012). Kui (2009), the first Chinese scholar having strategic thinking on low-carbon industrial cluster, raised its necessity and developing modes. Other scholars have mainly studied the topics about the developing direction of these clusters, more qualitative analysis but less quantitative proving, more macroscopic aspects but less specific regions (Huanfang and Zhenhua, 2012).

Thus, this article aims to research the spatial distribution and operation conditions of Chinese low-carbon industrial clusters, regarding every specific Chinese province as research unit. Location quotient method is used to conduct data analysis, which provides mathematical conclusions. Furthermore, another objective of this article is to study the performance of low-carbon companies in the clusters from a more microcosmic perspective. In a word, this article will provide a reference for further quantity analysis on low-carbon industrial cluster.

## RESEARCH METHODOLOGY

Location quotient (LQ), raised by P . Haggett, is an efficient method to determine the concentration of industries in a specific region (Shu-hen, 2009). It is widely used in industrial cluster research by Chinese scholars (Chang and Lili, 2006). For example, Shizhong et al. (2011) analyzed the cluster effect of clean energy industrial park in Baoding City with LQ. Yan and Xiaofeng (2010) identified that the tourist industry of Gansu Province had clustered in Lanzhou by applying LQ method. Yufang and Xuedong (2012) put forward suggestions on forestry cluster in Heilongjiang Province after measuring the level of cluster with LQ. Therefore, this article selected LQ method to identify the spatial location of the low-carbon industrial clusters in China.

Location quotient (LQ) means the ratio between two proportions. One proportion is the output value of one specific industry divided by the region's GDP. The other proportion is the whole industry output value divided by national GDP. The ration can reflect the relatively spatial concentration of every industry and identify the superior industry in the region (Yanggen, 2008).

Take the location quotient about the quantity of company for example. The calculation formula is as follows:

In the formula, $LQ_{ij}$ means the quotient of the quantity of company in industry I in region J. eij means the quantity of company in industry i in region j. means the quantity of company in the whole industries in region j. $\sum_{i=1}^{n} e_{ij}$ means the quantity of company nationally of industry i. $\sum_{j}^{n} \sum_{i=1}^{n} e_{ij}$ means the sum of all the companies in China. With the same method, the formula can also calculate the location quotient about production value or the quantity of employees.

If LQ ≥ 1, it means there exists industry cluster in this region. If LQ< 1, it represents there has been no industry cluster in this region. The bigger LQ is, the stronger the clustering effect. This article selects two location quotients. One is $LQ_1$ (about the quantity of company), and the other is $LQ_2$ (about the revenue).

### Collection of data

The provinces in China are regarded as specific investigative regions. The data about $\sum_{j}^{n} \sum_{i=1}^{n} e_{ij}$ and $\sum_{j}^{n} e_{ij}$ can be collected from Statistical Yearbook of China and Provincial Statistical Yearbook. In spite of the lack of existing data about low-carbon industrial cluster, information on the quoted low-carbon corporations can represent overall development of this industry. It is because they are outstanding companies with large scale and positive future, compared with other competitors. Thus, through collecting annual reports from Y2008 to Y2012 in Shanghai Stock Exchange and Shenzhen Stock Exchange, a sample was formed, including the information on main businesses, locations and revenues of 138 quoted low-carbon corporations from 24 provinces in China. Based on this sample, $LQ_1$ and $LQ_2$ were calculated. In this article, $LQ_1$ reflects the spatial distribution of the low-carbon industrial cluster in China in 2011, while $LQ_2$ reflects the operation change of this industry from 2008 to 2012.

### Results and discussion

**1. Analyze the spatial distribution of low-carbon industrial clusters in China in 2011, based on $LQ_1$:** From the overall perspective, low-carbon industries mainly clustered in the 13 provinces from the northeast, central region and southeast of China, like a “left parenthesis”.

Table 1 shows there are 13 $LQ_1$ whose values are more than 1, which means there are 13 provinces which have formed low-carbon industrial clusters, including Beijing, Fujian, Gansu, Guangdong, Heilongjiang, Hubei, Hunan, Jilin, Jiangsu, Inner Mongolia, Shanghai, Sichuan and Chongqing. Among these provinces, there are 4 $LQ_1$ whose values are more than 1.5, including Beijing, Gansu, Hubei and Jilin. Beijing is the first one. According to law of LQ, these 4 provinces have greater clustering effect.

**Table 1** Location quotient about the number of sample low-carbon companies in China in 2011 ( $LQ_1$ )

| Province | No. of low-carbon companies | Sum of all companies in the Province | Sum of all low-carbon companies in China | Sum of all companies in China | $LQ_1$ | Exist low-carbon industrial cluster or not? |
|---|---|---|---|---|---|---|
| Anhui | 2 | 214306 | 138 | 7331200 | 0.50 | No |
| Beijing | 22 | 360799 | 138 | 7331200 | 3.24 | Yes |
| Fujian | 7 | 278412 | 138 | 7331200 | 1.34 | Yes |
| Gansu | 3 | 57616 | 138 | 7331200 | 2.77 | Yes |
| Guangdong | 16 | 788631 | 138 | 7331200 | 1.08 | Yes |
| Hebei | 4 | 252808 | 138 | 7331200 | 0.84 | No |
| Henan | 3 | 269535 | 138 | 7331200 | 0.59 | No |
| Heilongjiang | 3 | 130121 | 138 | 7331200 | 1.22 | Yes |
| Hubei | 10 | 273217 | 138 | 7331200 | 1.94 | Yes |
| Hunan | 4 | 193955 | 138 | 7331200 | 1.10 | Yes |
| Jilin | 3 | 82914 | 138 | 7331200 | 1.92 | Yes |
| Jiangsu | 17 | 865414 | 138 | 7331200 | 1.04 | Yes |
| Jiangxi | 1 | 130247 | 138 | 7331200 | 0.41 | No |
| Liaoning | 2 | 312648 | 138 | 7331200 | 0.34 | No |
| Inner Mongolia | 2 | 97871 | 138 | 7331200 | 1.09 | Yes |
| Shandong | 5 | 649565 | 138 | 7331200 | 0.41 | No |
| Shanxi | 1 | 147432 | 138 | 7331200 | 0.36 | No |
| Shanghai | 11 | 397868 | 138 | 7331200 | 1.47 | Yes |
| Sichuan | 4 | 206310 | 138 | 7331200 | 1.03 | Yes |
| Tianjin | 2 | 166426 | 138 | 7331200 | 0.64 | No |
| Sinkiang | 1 | 57561 | 138 | 7331200 | 0.92 | No |
| Yunnan | 1 | 135280 | 138 | 7331200 | 0.39 | No |
| Zhejiang | 10 | 659000 | 138 | 7331200 | 0.81 | No |
| Chongqing | 4 | 176841 | 138 | 7331200 | 1.20 | Yes |

According to the Xu and Xurong (2010), the energy utilization rate is higher in East China than West China, which indicates that the low-carbon economy is more developed in east region than west region. The results of $LQ_1$ are in accordance with this existing research because most provinces, whose values of $LQ_1$ are bigger than 1, are in the East China.

To present the geographical distribution more visually, the value of $LQ_1$ was divided into four groups based on the following standards: $LQ_1 < 1$, $1 \leq LQ_1 \leq 1.5$, $LQ_1 \geq 1.5$ and "not included". Then they are marked out with different colors from shallow to deep as shown in Figure 1. It reflects that low-carbon industrial clusters locate mainly in the northeast, central region and southeast of China, like a "left parenthesis".

In Figure 1, those provinces with deeper colors turn out to be large provinces of industry, rather than coastal developed provinces. This phenomenon can be related to different key industries in different provinces. In these deep colored provinces, broader geographical space is beneficial to develop wind energy, solar energy and other low-carbon industry. However, in costal developed provinces, service industry and finance, account for a large proportion, much more than low-carbon industry. In those middle-scale provinces of industry, the strategic emphasis is usually product manufacturing.

The sample doesn't involve Tibet, Qinghai, Guizhou, Shanxi, Hainan, Taiwan, Hong Kong, Macao and others, totally to be 10 provinces and autonomous regions of China. Although it doesn't mean there are no low-carbon companies in these regions, it reveals the small amount of this industry. For example, Shanxi Province has a large industry of coal-mining but fewer low-carbon companies. Its serious resource dependence and environmental pollution have hindered the development of low-carbon industry (Lianlian, 2010).

From the inner perspective of provinces, low-carbon industries concentrated mainly on the provincial capitals and developed cities. By counting up the different

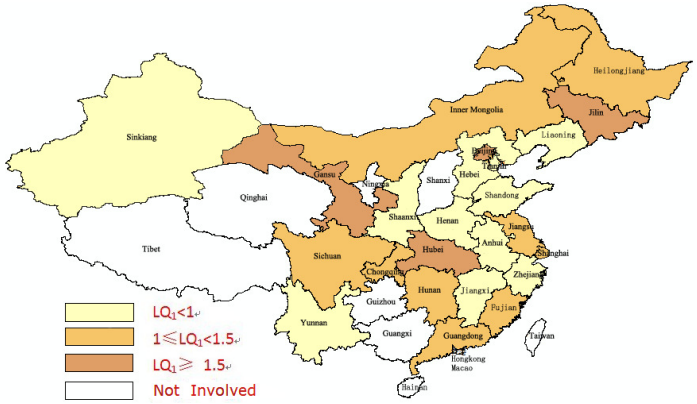


**Figure 1** Spatial distribution of Low-carbon industry clusters in China in 2011, based on $LQ_1$

**Table 2** Primary spatial distribution areas of low-carbon industry inside the provinces whose $LQ_1 \geq 1$ in China in 2011

| Province | No. of low-carbon companies | Primary spatial distribution areas | No. of low-carbon companies in the area | Quantity Ratio |
|---|---|---|---|---|
| Beijing | 22 | Haidian District | 9 | 40.9% |
| Fujian | 7 | Xiamen | 3 | 42.9% |
| Gansu | 3 | Lanzhou | 2 | 66.7% |
| Guangdong | 16 | Shenzhen | 5 | 31.3% |
| Heilongjiang | 3 | Harbin | 3 | 100.0% |
| Hubei | 10 | Wuhan | 8 | 80.0% |
| Hunan | 4 | Changsha | 2 | 50.0% |
| Jilin | 3 | Changchun | 2 | 66.7% |
| Jiangsu | 17 | Jiangyin | 6 | 35.3% |
| Inner Mongolia | 2 | Hohhot | 1 | 50.0% |
| Shanghai | 11 | Pudong new area | 3 | 27.3% |
| Sichuan | 4 | Chengdu | 2 | 50.0% |
| Chongqing | 4 | Yuzhong district | 2 | 50.0% |

**Table 3** Operating data of sample low-carbon companies from 2008-2012

| Province | Total revenue of low-carbon industry ( billion ) | | | | | | Rate of profit ( % ) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2012 | 2011 | 2010 | 2009 | 2008 | Growth Rate % | 2012 | 2011 | 2010 | 2009 | 2008 | Average profit rate % |
| Anhui | 11.57 | 11.1 | 9.1 | 7.2 | 6.9 | 66.70 | 2.4 | 4.1 | 4 | 3.8 | 1.1 | 3.1 |
| Beijing | 159.5 | 159.9 | 138.3 | 111.13 | 89.9 | 77.40 | 8.7 | 4.8 | 5.8 | 6.3 | 1.2 | 5.4 |
| Fujian | 120.1 | 88.7 | 66.9 | 49.7 | 47.5 | 152.80 | 1.5 | 2.1 | 1.6 | 1.3 | 1.3 | 1.6 |
| Gansu | 2.22 | 2.2 | 1.9 | 1.5 | 1.7 | 30.60 | 2.7 | 2.4 | 1.8 | -6.1 | 0.4 | 0.2 |
| Guangdong | 136.1 | 113.6 | 97.5 | 83.9 | 74.8 | 81.90 | 4.3 | 5 | 6.5 | 7.3 | 4.4 | 5.5 |
| Hebei | 9.6 | 11.3 | 12.6 | 10.2 | 8.4 | 13.80 | -14.2 | 1.5 | 5.7 | 6.1 | 8.2 | 1.5 |
| Henan | 23.9 | 21.7 | 18.2 | 9.4 | 8.9 | 169.40 | 7.1 | 5.9 | 5.3 | 4.7 | 2.1 | 5 |
| Heilongjiang | 11.7 | 10.7 | 9.0 | 6.9 | 6.2 | 88.50 | -1.5 | 2.6 | 3.5 | -7.8 | 4.9 | 0.3 |
| Hubei | 96.9 | 86.3 | 75.8 | 60.3 | 44.8 | 116.20 | 3.2 | 4.2 | 4.9 | 3.4 | 2.8 | 3.7 |
| Hunan | 11.4 | 12.4 | 10.9 | 8.3 | 6.3 | 81.10 | -0.5 | 3.4 | 4.4 | 3.4 | 2.6 | 2.7 |
| Jilin | 28.8 | 38.3 | 41.0 | 30.9 | 22.9 | 25.90 | -4 | 0.9 | 4.7 | 5.9 | 3.3 | 2.2 |
| Jiangsu | 37.5 | 41.4 | 37.5 | 24.4 | 25.2 | 48.70 | 1.2 | 5.9 | 6.5 | 6.2 | 3.4 | 4.6 |
| Jiangxi | 1.0 | 1.0 | 0.8 | 0.4 | 0.2 | 447.60 | 9.7 | 9.9 | 11.1 | -0.5 | 10.9 | 8.2 |
| Liaoning | 3.6 | 3.2 | 1.8 | 1.9 | 1.8 | 97.50 | 3.1 | 3.8 | 0.8 | 2.1 | 0.6 | 2.1 |
| Inner Mongolia | 51.2 | 48.9 | 34.9 | 26.9 | 24.9 | 105.90 | 6.3 | 10.8 | 4.4 | 2.6 | -6.1 | 3.6 |
| Shandong | 10.9 | 10.4 | 9.2 | 7.5 | 6.6 | 66.50 | 3.5 | 0.4 | 1.1 | 2.4 | -6.2 | 0.2 |
| Shanxi | 1.9 | 1.9 | 1.8 | 1.7 | 0.8 | 151.60 | 0.2 | 1.2 | 4.9 | 5 | 1 | 2.4 |
| Sichuan | 42.5 | 47.6 | 42.0 | 3.5 | 3.7 | 1065.10 | 7.1 | 8.1 | 7.6 | 49.7 | -1.1 | 14.3 |
| Tianjin | 7.6 | 6.7 | 8.4 | 5.8 | 4.1 | 87.40 | 1 | 4.2 | 6.6 | 46.8 | 60.4 | 23.8 |
| Sinkiang | 20.3 | 18.2 | 17.8 | 14.8 | 12.5 | 62.40 | 4.8 | 6.8 | 9.1 | 10.4 | 7.7 | 7.7 |
| Yunnan | 0.3 | 0.25 | 0.4 | 0.5 | 0.3 | 0.50 | -1.2 | -18 | 4.4 | -30.6 | 22 | -4.7 |
| Zhejiang | 35.2 | 34.5 | 31.3 | 22.9 | 24.3 | 45.30 | 2.9 | 5.7 | 4.6 | 4.3 | 3.3 | 4.2 |
| Chongqing | 35.2 | 31.4 | 37.5 | 29.0 | 16.2 | 117.70 | 4.8 | 3.4 | 5.7 | 4.1 | -0.3 | 3.5 |
| Shanghai | 527.2 | 483.8 | 408.8 | 1722 | 135.8 | 288.20 | 4.5 | 4.8 | 4.6 | 5.4 | 0.7 | 4 |

achieved 17 million ton emission reduction (Yingfa and Lin, 2010).In conclusion, these superiorities of developed cities have facilitated the clustering of low-carbon industry.

**2. Analyze the operation changes of low-carbon industrial clusters in China from 2008 to 2012, based on $LQ_2$:** During the five years, the sales revenues of all the 24 sample provinces had increased. The revenues of Shanghai were in the first place continuously, far more than others. Beijing, Guangdong, Fujian, Hubei followed Shanghai successively.

Based on the sales revenues of 138 quoted low-carbon companies from 2008 to 2012, the total sales revenues of low-carbon industry in the 24 sample provinces as well as their rates of profit were counted as shown in Table 3.

From the perspective of every province, Table 3 demonstrates the sales revenues of low-carbon industry in all sample provinces have all risen from 2008 to 2012, which reveals the enhancement of low-carbon awareness and the improvement of low-carbon economy. The revenues of Shanghai are in the first place continuously, far more than others. As for the growth rate, Sichuan ranks first place with 1065.1%, which results from its rapid development of new energy.

The sample revenue data of Shanghai low-carbon industry was proved to be accordant with the reality. On one hand, as an international metropolis, Shanghai creates an excellent developing circumstance with talented labors, enough capital and global trade platform (Ran, 2010). On the other hand, Shanghai has been establishing 3 low-carbon pilot sites, including Chongming Island ecological zone, Lingang City low-carbon practical area and Hongqiao low-carbon business district (HuaJia, 2012). Therefore, it is intelligible that Shanghai low-carbon economy is developing rapidly.

From the perspective of nationwide low-carbon industry, total sales revenues differ from year to year. Figure 2 was formed by summing up all the revenues for each year. This line chart reflects that the total sales revenues are on rise during the five years.

Based on Table 3, there were 9 sample provinces whose growth rates of sales revenue exceeded 100%, including Fujian, Henan, Hubei, Jiangxi, Inner Mongolia,

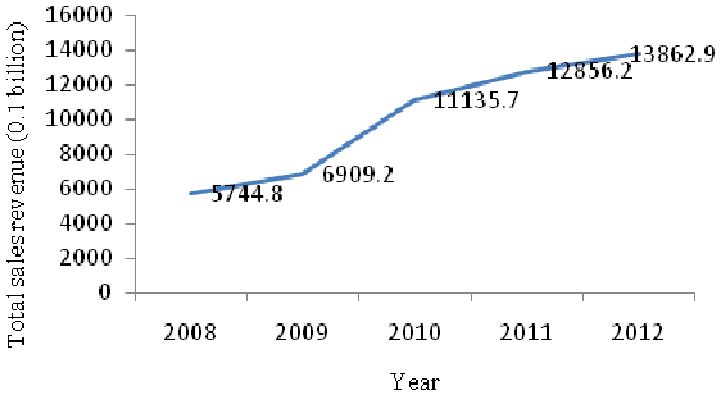


**Figure 2** Total sales revenues of all sample low-carbon companies from 2008 to 2012

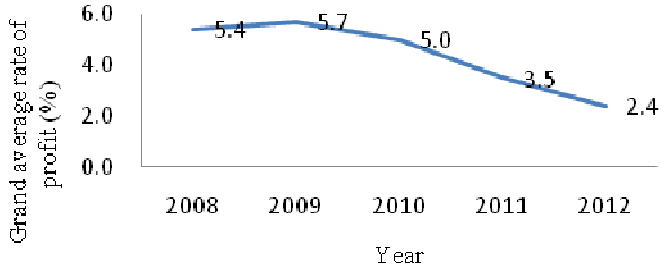


**Figure 3** Grand average rate of profit of sample low-carbon industry from 2008 to 2012

Shanxi, Sichuan, Chongqing and Shanghai. Combining the Table 1 and Table 3, it can be observed that there were 6 out of these 9 provinces whose values of $LQ_1$ were more than 1, containing Fujian , Hubei, Inner Mongolia , Sichuan, Chongqing and Shanghai. This finding illustrates there are a number of low-carbon companies with positive performance gathering in these regions. However, there were 3 provinces whose values of $LQ_1$ were less than 1, which reveals that there have existed low-carbon companies with considerable revenues in the areas, but it still remains small quantity.

In recent years, the average profit rates of sample low-carbon industry had slid gradually. What is worse, some provinces also suffered deficit of this industry. Through analysis, this phenomenon is related with the high technical cost and price restraint of low-carbon industry. The encouraging sales revenue doesn't mean the profit keeps increasing. According to Table 3, the average profit rate of Tianjin low-carbon industry ranked the first place by 23.8%, while Yunnan was the lowest by -4.7%. Furthermore, there were several provinces which suffered a deficit in most sample years except 2010. Particularly, there were 5 losing provinces in 2012, including Hebei, Heilongjiang, Hunan, Jilin and Yunan.

Based on Table 3, the average profit rates for each year were summed up and made into a line chart as presented in Figure 3. As the chart revealed, the grand average profit rate remained steady around 5% from 2008 to 2010, while it dropped down considerably from 2010.

This phenomenon can be explained with the high technical cost and price restraint of low-carbon industry. According to Shusheng (2012), on one hand, the low-carbon technology and equipment in China rely on import, which increases the technical cost. Besides, because low-carbon industry belongs to emerging industry, it lacks familiarity and confidence from investors

**Table 4** $LQ_2$ of low-carbon industry in sample provinces form 2008 to 2012

| Province | $LQ_2$ | | | | | |
|---|---|---|---|---|---|---|
| | 2012 | 2011 | 2010 | 2009 | 2008 | Growth rate |
| Anhui | 0.25 | 0.27 | 0.27 | 0.36 | 0.43 | -0.42 |
| Beijing | 3.36 | 3.61 | 3.55 | 4.55 | 4.45 | -0.25 |
| Fujian | 2.28 | 1.85 | 1.65 | 2.02 | 2.42 | -0.05 |
| Gansu | 0.15 | 0.16 | 0.16 | 0.22 | 0.30 | -0.50 |
| Guangdong | 0.89 | 0.78 | 0.77 | 1.06 | 1.12 | -0.20 |
| Hebei | 0.13 | 0.17 | 0.22 | 0.29 | 0.29 | -0.53 |
| Henan | 0.30 | 0.29 | 0.29 | 0.24 | 0.27 | 0.13 |
| Heilongjiang | 0.32 | 0.31 | 0.32 | 0.41 | 0.41 | -0.22 |
| Hubei | 1.63 | 1.62 | 1.74 | 2.34 | 2.18 | -0.25 |
| Hunan | 0.19 | 0.23 | 0.25 | 0.31 | 0.30 | -0.36 |
| Jilin | 0.90 | 1.33 | 1.71 | 2.11 | 1.96 | -0.54 |
| Jiangsu | 0.26 | 0.31 | 0.33 | 0.36 | 0.46 | -0.44 |
| Jiangxi | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 1.01 |
| Liaoning | 0.05 | 0.05 | 0.04 | 0.06 | 0.07 | -0.27 |
| Inner Mongolia | 1.20 | 1.26 | 1.09 | 1.38 | 1.76 | -0.32 |
| Shandong | 0.08 | 0.08 | 0.08 | 0.11 | 0.12 | -0.30 |
| Shanxi | 0.05 | 0.06 | 0.06 | 0.10 | 0.06 | -0.13 |
| Sichuan | 0.67 | 0.83 | 0.90 | 0.12 | 0.16 | 3.16 |
| Tianjin | 0.22 | 0.22 | 0.33 | 0.39 | 0.33 | -0.33 |
| Sinkiang | 1.01 | 1.01 | 1.18 | 1.71 | 1.65 | -0.39 |
| Yunnan | 0.01 | 0.01 | 0.02 | 0.04 | 0.03 | -0.62 |
| Zhejiang | 0.38 | 0.39 | 0.42 | 0.50 | 0.62 | -0.39 |
| Chongqing | 1.15 | 1.15 | 1.71 | 2.21 | 1.54 | -0.25 |
| Shanghai | 9.83 | 9.25 | 8.62 | 5.69 | 5.31 | 0.85 |

as well as consumers. Thus, the prices of low-carbon products are limited. In this case, industrial clusters can contribute to lower costs while increasing profits through sharing resources and stimulating creation among cluster members.

The list of those provinces whose $LQ_2$ values are more than 1 was included by the list of $LQ_1$, except for Sinkiang. Nevertheless, $LQ_2$ of 83.3% of sample provinces decreased from 2008 to 2012, except Shanghai whose values of $LQ_2$ increased slightly and reached the peak of about 10 in 2012.

Based on the formula (1), $LQ_2$ about sales revenues of the sample provinces from 2008 to 2012 were made into Table 4.

As Table 4 shows, there were 8 provinces whose values of $LQ_2$ in 2011 are more than 1, including Beijing, Fujian, Hebei, Jilin, Inner Mongolia, Sinkiang, Chongqing and Shanghai. The values of $LQ_1$ of these provinces were also greater than 1 except Sinkiang.

However, 83.3% of the sample provinces' $LQ_2$ declined from 2008 to 2012, which reflects that the proportion of low-carbon industry in the national economy has been decreasing. Why these provinces with increasing sales revenues turn out to be decreasing $LQ_2$? One of the reasons is that the growth rate of low-carbon industry is less than the growth rate of the whole economy in the province. Thus, according to the principle of LQ method, the ratio decreases at this situation.

Only the values of Henan, Jiangxi, Shanghai and Sichuan increased in different degrees. Among them, the values of $LQ_2$ of Shanghai increased slightly and reached the peak of about 10 in 2012. It can be explained by the constitution of Shanghai's samples in this data collection. Most sample low-carbon companies have big scales, such as Shanghai Automobile Industry Corporation and Shenergy Company. The total sales revenues of Shanghai's sample occupy respectively 23.6%, 24.9%, 36.7%, 37.6%, 38% of total sales revenues nationwide from 2008 to 2012. Therefore, considering that $LQ_1$ of Shanghai is only 1.47, it can be concluded that although the quantity of low-carbon industry in Shanghai doesn't take much proportion of all the industries, the capacity is great and keeps rising.

## Conclusion and future research

As a developing country with industrialization and urbanization, China must realize the low-carbon transition to balance economic development and environmental protection. Industrial clusters can enhance the competitiveness of low-carbon industry. This article analyzed the spatial distribution and operation changes of low-carbon industrial clusters in China based on location quotient method and the conclusions were as following:

The low-carbon industrial clusters mainly located in the northeast, central region and southeast of China, like a “left parenthesis”. Inner the provinces, low-carbon industries gathered in the provincial capitals and developed cities. In recent 5 years, the revenues of low-carbon industry in most provinces had increased, while the profit rates had declined with the effects of technical cost and price constraints. Among these provinces, Shanghai turned out to be a better development prospect with outstanding circumstance and supports from government.

The results are in accordance with the existing researches basically. The innovation is that this article studied 24 provinces, which shrank the research unit and provided reference proposal not only to the nation but also to specific provinces. For future research, it can focus on one specific region of China and collect more complete data including other non-quoted companies.

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