Empirical Research on Ecological Development Level of Resource-based Industries—Base on the data of the Silk Road Economic Belt Core Zone

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Abstract: Industrial ecology is the epitome of sustainable development in industry level, is one effective gateway to realizing green transformation. On the basis of industrial ecology development, including resource efficiency and environmental efficiency of ecological evaluation index system, this paper evaluates the level of industrial ecology development of resource-based industries in Xinjiang using entropy method. Research shows that the overall ecological development level of resource-based industries has remained at continuous improved trend with slow improvement in resource efficiency, and relative faster improvement in environmental efficiency. With economic development entering into the period of new normal at the end of the “twelfth five year plan”, the resource efficiency of ecological development of resource-based industries demonstrated a downward trend. The overall level of industrial ecology also faced with certain fluctuations, various ecological development level of resource-based industries also presented a downward trend. To promote ecological development of resource-based industries in Xinjiang, countermeasures and suggestions are initiated.

1. Introduction
The vision and action to push the co-building of Silk Road economic belt and 21st century maritime Silk Road puts forward that Xinjiang should be shaped as core region of Silk Road economic belt. Located in the boarder of China’s northwest, Xinjiang is adjacent to central Asian countries. It is the venue of three corridors in northern, middle and southern Silk Road economic belt which boasts rich mineral resources and has established a relatively sound resources-oriented industrial system with obvious characteristics of high energy consumption, high emission and poor efficiency in economic growth. The implementation program of accelerating the construction of core area building in Xinjiang Silk Road economic belt further clarified the connotation of silk road economic belt’s core area and put forward the construction plan to build large-scale gas and oil producing and processing and the reserve base of large-scale coal power and coal chemical base. The development level of resource-based industry ecologicalization on the basis of fossil energy determines the coordinated sustainable development of economy in core area of Silk Road economic belt. To promote the construction of core area of Silk Road economic belt and realize the sustainable development of Xinjiang’s economy, it is imperative to achieve the transformation of ecologicalization in resources-based industries. Under the guidance of the industrial ecology theory, the paper plans to explore on the development level of recourse-based industrial ecology in Xinjiang, aiming to provide theoretical basis for the smooth implementation of industrial development strategy of Silk Road economic belt.
2. Research method and data resources

2.1 The evaluation method on the development of resource-based industrial ecology

Industrial ecology refers to quantitative indicators reflecting the degree of industrial ecology development. The paper selects comprehensive indexes of representative industrial ecology development and applies entropy method to evaluate the ecology development level of resources-based industries in Xinjiang. The major principle of this method: nth objectives, mth evaluation index, forming the matrix of primary index X=(x_{ij})^{mn}. For certain index x_{ij}, the more disparity of the index value x_{ij}, the greater role it plays in comprehensive assessment. If all the index equals to each other, then the index is inoperative in comprehensive assessment. In order to be more accurate in indicating the weight function of each index of ecologicalization of resources-based industries in Xinjiang, the paper plans to adopt the panel data of various index in Xinjiang’s resources-based industries ecologicalization to calculate its weight.

2.2 Processing method for original data of resources-based industrial ecology development

The paper selects index that reflects different aspects and level of ecologicalization development in Xinjiang’s resources-based industries. Therefore, the data needs to be standardized. The paper utilizes standardized methods to process the raw data.

For positive index, making
\[ y_{ij} = \frac{(\text{max} x_{ij} - \text{min} x_{ij})}{(\text{max} x_{ij} - \text{min} x_{ij})}; \]

For negative index, making
\[ y_{ij} = \frac{(\text{max} x_{ij} - x_{ij})}{(\text{max} x_{ij} - \text{min} x_{ij})}; \]

max x_{ij} - min x_{ij} respectively refers to the maximum and minimum value of samples under the j index and stands for various index value after standardization.

3. Measurement of ecological development level of resource-based industries in Xinjiang

3.1 Building up index system

Industrial ecology is an extension and embodiment of sustainable development at the industry level. Through industrial intergrowth and the extension of value chain as well as the improvement of industrial system, the efficiency of resource usage can be maximized while minimizing the negative impact of economic growth on the environment. By following scientific, systematical, and feasible principle, the evaluation index system of ecological development of resource-based industries in Xinjiang is built from the dimension of resource efficiency and environmental efficiency. The formula of environmental efficiency calculation refers to: environmental efficiency = values of product or service/ environmental load.

As shown in table 1:

| Aim                  | Rule                        | Index                                      | Weight  |
|----------------------|-----------------------------|--------------------------------------------|---------|
| industrial ecology   | index of resource efficiency| energy consumption per unit of industrial material consumption of gross industrial output | 0.0453  |
|                      |                             | output value of industrial wastewater per unit | 0.0668  |
|                      | index of environmental efficiency | output value of industrial waste gas per unit | 0.1197  |
|                      |                             | output value of industrial solid wastes per unit | 0.3779  |
|                      |                             | output value of industrial solid wastes per unit | 0.3903  |

3.2 The overall level of ecologicalization development of resource-based industries in Xinjiang

The ecologicalization development of resources-based industries in Xinjiang demonstrated a fluctuating upward trend which remained a relatively low overall level. In 2015, the index of ecologicalization development of resources-based industries reached 23.73, an increase of 11.64 point compared to the year of 2001, increasing by 4.9% on the year basis. The resource efficiency of ecologicalization
development of resources-based industries in Xinjiang are experiencing fluctuated period with a slow development pace. The environmental efficiency of industrial ecologicalization has a relative large increase amplification with an annual increase of 11.2%.

3.3 Comparative analysis of different types of ecological development of resource-based industries in Xinjiang

Entropy value method is used to determine the weight of each indicator, and evaluate development level of industrial ecologicalization of seven category of resource-based industries based on standardizing values of each index. As it shown in Table 2:

Table 2 Industrial ecology development level of various resource-based industries

| Year | coal mining and washing industry | petroleum and natural gas extraction industry | petroleum processing, coking and nuclear fuel processing industry | chemical materials and chemical products manufacturing industry | raw chemical fiber manufacturing industry | rubber and plastic products industry | electricity and heating production and supply industry |
|------|---------------------------------|---------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|----------------------------------------|--------------------------------------|-----------------------------------------------------|
| 2001 | 8.76                            | 18.88                                       | 10.69                                                         | 8.68                                                         | 6.52                                   | 21.34                                | 6.31                                               |
| 2002 | 8.30                            | 19.29                                       | 10.65                                                         | 8.73                                                         | 6.16                                   | 22.21                                | 5.79                                               |
| 2003 | 9.13                            | 19.52                                       | 11.24                                                         | 9.71                                                         | 6.42                                   | 28.21                                | 6.34                                               |
| 2004 | 4.94                            | 19.82                                       | 12.07                                                         | 8.85                                                         | 7.62                                   | 28.98                                | 8.07                                               |
| 2005 | 7.86                            | 21.37                                       | 12.98                                                         | 8.47                                                         | 9.25                                   | 38.85                                | 7.99                                               |
| 2006 | 7.12                            | 22.19                                       | 14.58                                                         | 8.44                                                         | 9.77                                   | 51.64                                | 8.41                                               |
| 2007 | 7.18                            | 22.81                                       | 15.78                                                         | 8.28                                                         | 9.05                                   | 74.57                                | 7.76                                               |
| 2008 | 9.10                            | 24.32                                       | 18.37                                                         | 9.35                                                         | 8.04                                   | 91.84                                | 8.56                                               |
| 2009 | 8.64                            | 19.84                                       | 17.32                                                         | 9.19                                                         | 9.68                                   | 79.39                                | 7.81                                               |
| 2010 | 8.71                            | 20.70                                       | 18.56                                                         | 9.54                                                         | 10.27                                  | 87.61                                | 8.61                                               |
| 2011 | 9.33                            | 22.25                                       | 22.93                                                         | 9.03                                                         | 10.00                                  | 87.95                                | 8.05                                               |
| 2012 | 9.37                            | 21.62                                       | 19.79                                                         | 9.10                                                         | 10.00                                  | 78.44                                | 8.78                                               |
| 2013 | 8.92                            | 19.92                                       | 20.15                                                         | 8.92                                                         | 9.93                                   | 87.01                                | 8.96                                               |
| 2014 | 8.98                            | 21.50                                       | 22.06                                                         | 8.81                                                         | 9.78                                   | 91.47                                | 10.54                                              |
| 2015 | 9.03                            | 18.93                                       | 18.05                                                         | 8.12                                                         | 9.47                                   | 91.69                                | 9.11                                               |

Source of data: calculations based on the Statistical Yearbook of Xinjiang (2002-2016)

Conclusions can be draw from table three that great gap existed in the development of different types of resource-based industries ecologicalization. Petroleum and natural gas extraction, petroleum processing, coking and nuclear fuel processing, rubber and plastic products industry have achieved relative higher development level with an upward trend, among which rubber and plastic products industry ranks the top regarding the development level of ecologicalization. Coal mining and washing industry, chemical fiber manufacturing industry, electricity and heating production and supply industry are experiencing greater fluctuations in terms of its development level with slow increasing trend.

3.4 Resource efficiency of various ecological resource-based industries in Xinjiang

The study applies entropy value method to further measure resource efficiency of various resource-based industry ecological development in Xinjiang.
Table 3 Resource efficiency of ecological development of various resource-based industries

| Year | coal mining and washing industry | petroleum and natural gas extraction industry | petroleum processing, coking and nuclear fuel processing industry | chemical raw and chemical products manufacturing industry | chemical fiber manufacturing industry | rubber and plastic products industry | electricity and heating production and supply industry |
|------|---------------------------------|---------------------------------------------|-------------------------------------------------|-------------------------------------------------|---------------------------------|---------------------------------|--------------------------------------------------|
| 2001 | 8.506                           | 7.754                                       | 9.192                                           | 8.052                                           | 5.935                           | 9.595                           | 5.990                                            |
| 2002 | 8.027                           | 7.669                                       | 9.036                                           | 8.015                                           | 5.612                           | 9.577                           | 5.419                                            |
| 2003 | 8.772                           | 8.033                                       | 9.184                                           | 8.398                                           | 6.023                           | 9.657                           | 5.964                                            |
| 2004 | 4.508                           | 8.222                                       | 9.410                                           | 7.564                                           | 7.283                           | 6.476                           | 7.522                                            |
| 2005 | 7.282                           | 8.774                                       | 9.218                                           | 7.091                                           | 8.853                           | 9.102                           | 7.345                                            |
| 2006 | 6.315                           | 8.907                                       | 9.324                                           | 6.930                                           | 9.362                           | 8.644                           | 7.579                                            |
| 2007 | 6.129                           | 9.006                                       | 9.085                                           | 6.891                                           | 8.540                           | 9.408                           | 6.791                                            |
| 2008 | 7.663                           | 9.221                                       | 9.514                                           | 7.452                                           | 7.521                           | 9.462                           | 6.740                                            |
| 2009 | 7.264                           | 8.775                                       | 9.408                                           | 7.378                                           | 9.221                           | 9.156                           | 6.116                                            |
| 2010 | 6.692                           | 8.990                                       | 9.511                                           | 7.695                                           | 9.684                           | 9.447                           | 6.038                                            |
| 2011 | 7.212                           | 9.253                                       | 9.713                                           | 7.256                                           | 9.559                           | 10.254                          | 6.032                                            |
| 2012 | 7.310                           | 9.182                                       | 9.618                                           | 7.157                                           | 9.682                           | 9.258                           | 6.178                                            |
| 2013 | 6.934                           | 8.871                                       | 9.517                                           | 6.842                                           | 9.609                           | 9.068                           | 5.553                                            |
| 2014 | 6.792                           | 8.672                                       | 9.302                                           | 6.507                                           | 9.459                           | 8.268                           | 5.377                                            |
| 2015 | 6.836                           | 7.840                                       | 9.078                                           | 5.650                                           | 9.184                           | 9.043                           | 3.433                                            |

Source of data: calculations based on the Statistical Yearbook of Xinjiang (2002-2016)

Table 3 shows that resource efficiency is generally low regarding different types of ecological development of resource-based industries in Xinjiang with an overall downward trend, among which resource efficiency of chemical raw materials, chemical products manufacturing industry, electricity and heating production and supply industry have decreased in the greatest degree. Respectively, it decreased from 8.052 in 2001 and 5.99 to 5.65 and 3.433 in 2015. Resource efficiency of chemical fiber manufacturing industry showed a gradual rising trend, which raised up from 5.935 in 2001 to 9.184 in 2015.

3.5 Environmental efficiency of various resource-based industries ecological development

The study applies entropy value method to measure environmental efficiency of various resource-based industries ecological development. As it shown in Table 4:

Table 4 Environmental efficiency of various resource-based industries ecological development

| Year | coal mining and washing industry | petroleum and natural gas extraction industry | petroleum processing, coking and nuclear fuel processing industry | chemical raw and chemical products manufacturing industry | chemical fiber manufacturing industry | rubber and plastic products industry | electricity and heating production and supply industry |
|------|---------------------------------|---------------------------------------------|-------------------------------------------------|-------------------------------------------------|---------------------------------|---------------------------------|--------------------------------------------------|
| 2001 | 0.249445                       | 11.12304                                   | 1.50074                                         | 0.629821                                        | 0.588039                       | 11.74279                       | 0.314813                                       |
| 2002 | 0.277697                       | 11.62374                                   | 1.615405                                        | 0.716381                                        | 0.545221                       | 12.62894                       | 0.367944                                       |
| 2003 | 0.357327                       | 11.48555                                   | 2.057219                                        | 1.316479                                        | 0.392163                       | 18.55502                       | 0.379319                                       |
| 2004 | 0.431158                       | 11.59322                                   | 2.664649                                        | 1.286231                                        | 0.342018                       | 22.50544                       | 0.546017                                       |
| 2005 | 0.579204                       | 12.59452                                   | 3.76165                                         | 1.380361                                        | 0.399422                       | 29.74897                       | 0.649197                                       |
| 2006 | 0.802972                       | 13.28065                                   | 5.257407                                        | 1.508254                                        | 0.410689                       | 42.99547                       | 0.829848                                       |
| 2007 | 1.047863                       | 13.80287                                   | 6.697806                                        | 1.385431                                        | 0.509008                       | 65.16617                       | 0.967305                                       |
| 2008 | 1.439297                       | 15.1024                                    | 8.852019                                        | 1.897924                                        | 0.520823                       | 82.37519                       | 1.825385                                       |
Table 4 shows that great gap existed environmental efficiency of various resource-based industries ecological development in Xinjiang, while petroleum and gas extracting industry, rubber and plastic products industry remains a relative higher level of environmental efficiency. Resource efficiency has been improving on the following industries: coal mining and washing industry, petroleum processing, coking and nuclear fuel processing, chemical raw material and chemical products manufacturing industry, rubber and plastic products industry, electricity and heating production and supply industry, among which rubber and plastic products have a comparative higher development pace. It raised from 11.74 in 2011 to 82.62 in 2015 while the resource efficiency of chemical fiber manufacturing industry decreased from 0.59 in 2011 to 0.28 in 2015.

### 4. Conclusions

Research shows that the overall ecological development level of resource-based industries has remained at continuous improved trend with slow improvement in resource efficiency, and relative faster improvement in environmental efficiency. With economic development entering into the period of new normal at the end of the “twelfth five year plan”, the resource efficiency of ecological development of resource-based industries demonstrated a downward trend. The overall level of industrial ecology also faced with certain fluctuations, various ecological development level of resource-based industries also presented a downward trend. Petroleum and natural gas exploitation industry, oil processing, coking and nuclear fuel processing, and rubber and the plastic products industry remain at a high development level regarding the ecological development with relative higher resource efficiency and environmental efficiency, which boasts outstanding advantage in terms of the environmental efficiency. Coal mining and washing industry, chemical fiber manufacturing industry, electricity and thermal production and supply industry demonstrated relative greater fluctuation and swifter improvement of environment efficiency. Chemical raw material and chemical products manufacturing industry showed the trend of decline with fluctuation, and the resource efficiency is declining and the environment efficiency is improving.

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### References

[1] Allenby B R. 1994. *The greening of industrial ecosystems*. Pittsburgh: National Academies Press.

[2] Hawken, P., Lovins, A. B., & Lovins, L. H. 2010. *Natural capitalism : the next industrial revolution*. London: Earthscan Publications.

[3] Deng bo, Zhang Xuejun, etc. 2011. *Regional Ecological Efficiency Study based on the three stage DEA model*. Journal of China soft science, vol 1, P 92-99.
[4] Cheng Xiaojuan, Han Qing-lan, etc. 2013. *China Coal Industry Ecological Efficiency Study based on the PCA - DEA combination model*. Journal of resources science, vol 6, P 1292-1299.

[5] Wang Jing, Kong Fanbin. 2012. *China Regional Ecological Efficiency Assessment Research - in the case of Poyang lake ecological economic zone*. Journal of economic geography, vol 12, P 103-109.

[6] Liu Genyao, Sheng Long, Tang Chenhua. 2012. *Static and dynamic analysis of China's industrial ecology - empirical research based on the provincial data*. Journal of China industrial economy, vol 3, P 147-159.