Study on the Atmospheric Environmental Efficiency of the Silk Road Economic Belt of China Based on Energy conservation and Emission Reduction

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Abstract. Based on SBM-Undesirable model, this paper evaluated air environmental efficiency of 8 provinces of the Silk Road Economic Belt of China during the period of 2010—2017, and investigated the temporal-variation and energy conservation and emission reduction potential. Empirical analysis shows that the overall atmospheric environmental efficiency of Silk Road Economic Belt is still at low point but presents a mild rising trend over the period 2010—2017, regional differences are remarkable, and it has great potential of energy conservation and emission reduction in the future.

1. Introduction

In 2013, Chinese government proposed a major initiative to jointly build the "Silk Road Economic Belt" and the "21st century Maritime Silk Road", which put the green concept of ecological civilization construction on priority. However, due to the high consumption and low utilization of energy and the high-intensity emission of air pollutants such as SO₂ and NOₓ, the air pollution problem along the line has become increasingly serious. Therefore, the scientific measurement and analysis of the Silk Road Economic Belt’s atmospheric environmental efficiency can provide data reference and theoretical basis for the sustainable economic development and ecological civilization construction in China.

DEA (date envelopment analysis) method is widely used by scholars at home and abroad. Since it was first proposed by A Charnes and W W Cooper in the late 1970s [1,2], it has been widely used and developed in the research of energy and environmental efficiency. J L Hu et al. first used DEA method to calculate the TFEE index of 29 provinces in China, and verified the hypothesis that the energy efficiency is directly proportional to the economic growth of China [3]. With the development of energy and environmental efficiency research, scholars at home and abroad begin to consider the impact of input and output slack variables in the process of energy efficiency measurement. Y Choi et al. measured China’s energy efficiency and CO₂ emission efficiency based on the SBM model of slack measure, and estimated its potential emission reduction and marginal emission reduction cost [4]. In recent years, using DEA to deal with unexpected output has become a hot topic of domestic and foreign scholars, H. George et al. summarized four treatment methods of unexpected output in DEA [5]. The above researched proved that DEA method is feasible in the measurement of energy...
environmental efficiency, and also provides reference and model support for other scholars in the measurement of atmospheric environmental efficiency index. At present, there are few researches on the atmospheric environmental efficiency of the Silk Road Economic Belt. This paper evaluated air environmental efficiency of 8 provinces of the Silk Road Economic Belt of China during the period of 2010—2017 Based on SBM-Undesirable model.

2. Methods and models

2.1. SBM-Undesirable model

This model is improved by K Tone based on non radial and non angular SBM model with slack variable, which introduces "unexpected output" by splitting output variable [6]. According to "unexpected output", build a possible production set. Suppose that there is N (n = 1, …, N) decision cells, including M (m=1, …, M) factor inputs and P (p = 1, …, P) factor outputs, which are divided into P1, expected outputs and P2 unexpected outputs. Define matrix input indicators \( X \in R^{m,n}_+ \), Expected output index \( Y^g \in R^{p,2}\), Unexpected output index \( Y^b \in R^{p,2}_-\), In the case of constant returns to scale (CRS), the set of production possibilities:

\[
G = \{(x, y^g, y^b) | x \geq X \lambda, \ y^g \leq Y^g \lambda, \ y^b \geq Y^b \lambda, \ \lambda \geq 0\}
\]

\[
\min \rho = \frac{1 - \frac{1}{M} \sum_{m=1}^{M} s^m}{1 + \frac{1}{P_1 + P_2} \left( \sum_{i=1}^{P_1} s^{y^g} + \sum_{i=1}^{P_2} s^{y^b} \right)}
\]

\[
S.T. x_0 = X \lambda + s^-, \ y^g = Y^g \lambda + s^{y^g}, \ y^b = Y^b \lambda + s^{y^b}, \ \lambda \geq 0, \ s^{-} \geq 0, \ s^{y^g} \geq 0, \ s^{y^b} \geq 0
\]

\( \rho \) is the value of atmospheric environmental efficiency, \( s^- \), \( s^{y^g} \), \( s^{y^b} \) is the slack value of factor input, expected output and unexpected output, \( \lambda \) is the weight matrix. \( \rho \) On \( s^- \), \( s^{y^g} \), \( s^{y^b} \) strictly monotone decreasing, and \( 0 \leq \rho \leq 1 \), if and only if \( \rho = 1 \), current DMU is valid, Otherwise, it is invalid.

3. sample variables and data

Considering the availability of data, the sample investigation period is 2010—2017, and the research object is the main 8 provinces along the Silk Road Economic Belt. Data of the above indicators can be obtained directly from China Statistical Yearbook, The descriptive statistical characteristics of input-output variable data are shown in Table 1.

| Variable          | Units          | Min            | Max            | Mean           | Std.Dev         |
|-------------------|----------------|----------------|----------------|----------------|-----------------|
| Input factors     |                |                |                |                |                 |
| Labor             | Million workers| 307.650        | 2998.890       | 1596.595       | 940.068         |
| Capital RMB Billion| 2786.836     | 25064.281      | 12804.812      | 6470.016       |
| Energy            | Million tons of coal | 2814.570     | 17391.700      | 8129.471       | 3376.812        |
| Desirable outputs | GDP RMB Billion| 1070.381       | 16343.242      | 7417.766       | 4498.344        |
| SO2               | 104tons        | 9.240          | 91.680         | 48.563         | 22.739          |
| NOX               | 104tons        | 7.230          | 88.690         | 42.029         | 20.490          |
| Dust              | 104tons        | 8.330          | 81.390         | 31.697         | 16.789          |
4. Empirical measurement and result analysis

4.1. Temporal-variation of atmospheric environmental efficiency

According to formula (1) and formula (2), the atmospheric environmental efficiency of 8 provinces along the Silk Road Economic Belt in 2010-2017 is calculated based on CRS, the results are shown in Table 2.

![Figure 1: Atmospheric environmental efficiency of 8 provinces of the Silk Road Economic Belt during 2010—2017](image1)

According to figure 1, The mean value of atmospheric environmental efficiency of SX, GS and other provinces in Northwest China and GX, CQ and YN provinces in Southwest China is between 0.463 and 0.214. Because the northwest and southwest Regions are located in the inland of China, the ecological and natural conditions are relatively complex, and the formation and accumulation of air pollutants are difficult to spread. The economic foundation of some provinces and cities is weak, the level of industrial structure is low, and the level of technology is backward, which makes the atmospheric environmental efficiency at a low level for a long time.

4.2. Redundancy analysis of atmospheric environmental efficiency

According to formula (1), calculate the redundancy rate of atmospheric environmental efficiency of 8 provinces along the Silk Road Economic Belt during 2010-2017. In order to provide scientific and reasonable improvement direction for atmospheric environmental efficiency, the potential of energy conservation and emission reduction of input-output variables in each province is analyzed. The results are shown in Figure 2.

![Figure 2: Redundancy ratio of input and output variables of 8 provinces of the Silk Road Economic Belt during 2010—2017](image2)

According to figure 2, in addition to energy input, the redundancy rates of the other three unexpected output variables are presented SO2 > DUST > NOX. From the dynamic angle, The redundancies of energy input and unexpected output are decreasing with each passing year, this is consistent with the time trend of annual increase of atmospheric environmental efficiency given above.
5. Conclusion

According to the research results, it can be found that in the six years from the initiation to the implementation of the initiative, although the atmospheric environmental efficiency of the areas along the line in China is still low, it shows a positive trend of increasing year by year and has great potential for energy conservation and emission reduction. In order to better promote the construction of ecological civilization, we should take green as the base color of the Silk Road Economic Belt. The provinces should further improve energy utilization rate and industrial structure, introduce and promote the green technology focusing on energy conservation and emission reduction, so as to prevent and control air pollution from the source.

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