Analysis of Carbon Emission Efficiency in Belt and Road Agriculture

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Abstract: This paper will calculate the carbon emissions and their growth rates in 30 regions except Tibet and Hong Kong, Macao and Taiwan. It will also outline 17 regions with strategic priorities along the Belt and Road: Xinjiang, Shaanxi, Gansu, Ningxia, Qinghai, Inner Mongolia, Heilongjiang, Jilin, Liaoning, Guangxi, Yunnan, Shanghai, Fujian, Guangdong, Zhejiang, Hainan and Chongqing. It will also calculate the carbon emissions share of major agricultural carbon sources. Based on the analysis of the influencing factors of agricultural carbon emission efficiency in the belt and road initiative, the SBM model and ML model are used to evaluate and analyze the agricultural carbon emission efficiency in the belt and road initiative region from the static and dynamic perspectives respectively. The results show that: (1) the average carbon emission in the belt and road initiative region from 2014 to 2017 is 4.4396 million tons, which is lower than the national average of 5.0883 million tons; (2) animal husbandry and cultivation activities become the two major sources of carbon emission; (3) from DEA model, it can be seen that the belt and road initiative region accounts for 5 of the 8 regions with effective carbon emission in 2017, while Heilongjiang province has the largest range of arable land and total power of agricultural machinery to be adjusted among the regions with carbon emission efficiency of 0.75 to 1. (4) During 2014-2017, the average ML index in the belt and road initiative region is 1.042, which is greater than 1, of which the average tech index is 1.045 and the average effch idex is 0.998, indicating that the overall agricultural carbon emission efficiency is on the rise.

1. Introduction
Global warming is becoming more and more serious, and the negative effects of carbon emissions have also attracted the attention of various countries. Sustainable development has received widespread attention [1]. As the largest developing country in the world and a big carbon emitter, China bears great responsibility and pressure. The implementation of the "the belt and road initiative" strategy has brought new vitality to the regional agricultural generate.

According to statistics, carbon emissions from agricultural production account for about 14.9% of the total global greenhouse gas emissions[2], and agriculture has become the second important source of greenhouse gas[3]. As a large agricultural country, China's agricultural carbon emissions account for about 17% of the national emissions. Therefore, how to effectively control and inhibit agricultural carbon emissions has become an urgent problem. However, there are few targeted analyses based on the characteristics of inland areas in the belt and road initiative. Therefore, this paper will analyze the changes of agricultural carbon emissions and the reasons that affect the efficiency of agricultural carbon emissions since the implementation of the Belt and Road Strategy.

In terms of research methods, Fare(1989) first summarized and put forward DEA model for
evaluating environmental efficiency under all factors\cite{4}. Jennifer a. burneya, steven j. davisc, david b. lobell and other scholars studied agricultural greenhouse gas emissions by DEA method in (2010)\cite{5} However, carbon emission is an undesirable output in agricultural production. Compared with the traditional DEA method, it has certain defects in the treatment of this variable: the two types of models included in DEA are radial models, and the improveable quantity in radial direction is the source of inefficiency when calculating the efficiency of radial models, which sometimes cannot make the efficiency value most effective; when several decision elements are valid and exist at the same time, in-depth comparison cannot be made\cite{6}; moreover, if carbon emissions are used as input or the reciprocal is taken, it will lose its economic significance, and the super-efficiency SBM model which considers non-radial and non-oriented non-expected output can well solve the above problems\cite{7}. At the same time, this paper uses ML index to study the dynamic changes of carbon emission efficiency. The advantage of ML index is that it can make up for the defects in dealing with carbon emissions, solve the existing problems and enhance the research effect.

Although DEA and Malmquist indexes are used by many scholars, the research on agricultural carbon emission efficiency based on super-efficiency SBM model and ML index is still lacking. Based on the particularity of the agricultural system and the collected literature, this paper explores and evaluates the agricultural carbon emission efficiency under the background of "the belt and road initiative" from both static and dynamic perspectives by using the super-efficiency SBM model with unexpected output and ML index that specially processes panel data, and at the same time summarizes the suggestions for improving the agricultural carbon emission efficiency.

2. Calculation and Analysis of Carbon Emission

As agricultural carbon emissions are numerous and miscellaneous, it is not easy to accurately obtain carbon emissions. In order to be more organized, this paper classifies the main sources of agricultural carbon emissions. This paper divides the sources of carbon emissions into the following five aspects:

| Sources of carbon emissions from agriculture | Expression |
|---------------------------------------------|------------|
| The production and use of fertilizer pesticide and agricultural film. | The application amount of chemical fertilizer pesticide and agricultural film. |
| Diesel oil for agricultural machinery. | The amount of diesel oil used for agriculture. |
| Agricultural irrigation. | Effective irrigation area. |
| Real Tillage. | Agricultural acreage. |
| Manure treatment of pigs, cows and sheep. | The average number of pigs, cattle and sheep. |

The specific carbon emission calculation formula is:

$$C = \sum C_i = \sum T_i \times \delta$$  \hspace{1cm} (1)

Among them, $C$ represents the total amount of agricultural carbon emissions (10,000 tons), $C_i$ represents the total amount of carbon emissions from Class I carbon sources, $T_i$ represents the number of Class I carbon sources, and $\delta$ represents the carbon emission coefficient of Class I carbon sources. The coefficients corresponding to each carbon source are shown in Table2 below:

| Carbon emission source | Coefficient | Unit | Origin |
|------------------------|-------------|------|--------|
| Fertilizer             | 0.8956      | kg CE/kg | ORNL   |
| Pesticide              | 4.9341      | kg CE/kg | ORNL   |
| Agricultural film      | 5.8         | kg CE/kg | IREEA  |
| Diesel oil for agricultural machinery | 0.5927 | kg CE/kg | IPCC   |
The above carbon emission source data are obtained through 2019 China Rural Statistics Yearbook, in which the carbon emissions of pigs, cattle and sheep are calculated according to the methods of Hu Xiangdong and Wang Jimin (2010). According to formula (2-1), the total amount of agricultural carbon emissions and the average value of carbon emissions in 30 regions during 2014-2017 can be calculated, sorted in ascending order, and a line chart is drawn, as shown in Figure 1. At the same time, according to the calculated carbon emission quantity and total carbon emission quantity of each carbon emission source, the carbon emission proportion of each carbon emission source in the key delineated areas of the belt and road initiative from 2014 to 2017 can be obtained, as shown in Table 3:

![Average carbon emissions](image)

**Figure 1. Mean carbon emissions**

| Fertilizer | Pesticide | Agricultural film | Diesel oil | Agricultural irrigation | Land tillage | Pigs | Cows | Sheep |
|------------|-----------|-------------------|-----------|-------------------------|--------------|------|------|-------|
| 31.47%     | 5.09%     | 9.19%             | 9.46%     | 0.08%                   | 0.31%        | 6.62%| 29.37%| 8.40% |

### 3. Static Evaluation of Super-efficient SBM Model

#### 3.1 Index Selection

In terms of input, combined with economic thoughts, the production factors can be divided into: human input, material input and financial input. In this paper, the selection of indicators, human input is expressed by the number of employees in the primary industry; the area of cultivated land used for material input, the total power of agricultural machinery and the amount of chemical fertilizer applied are expressed. Financial input is expressed by investment in fixed assets in agriculture, forestry, animal husbandry and fishery. According to the characteristics of SBM model, the output is divided into expected output and non-expected output, in which expected output is expressed by total output value of agriculture, forestry, animal husbandry and fishery and afforestation area, and non-expected output is expressed by agricultural carbon emissions. In order to study the carbon emission efficiency better, carbon emission is used as the unexpected output.

#### 3.2 Data Sources

The data of various input and output indicators are all from China Rural Statistical Yearbook,
provincial statistical yearbooks from 2014 to 2017, and national data network. From this, a statistical study was carried out on 30 provinces and cities nationwide, and a comparative analysis was made on 17 provinces delineated by the strategic priorities along the Belt and Road. Agriculture in 30 regions is taken as DMU to analyze its agricultural carbon emissions in 2017, and the data are imported into maxdea software. The results are shown in Table 4 below. Secondly, the selected 17 key areas in the belt and road initiative are compared with other provinces and cities across the country.

Table 4.2017 SBM analysis of China's 30 provinces' agricultural carbon emissions super-efficiency

According to the above table, it can be seen that in 2017, among the 30 provinces, the efficiency value of agricultural carbon emissions reached 1, i.e. 8 achieved effective carbon emissions. Among the 17 key regions in the belt and road initiative, Fujian, Inner Mongolia, Qinghai, Shanghai and Zhejiang have 5 regions with effective carbon emissions. The proportion of regions (17/30) is equivalent to that of regions with effective carbon emissions (5/8), and the proportion of the latter is slightly higher than that of the former. After that, Hainan, Guangdong, Heilongjiang, Chongqing, Xinjiang and Liaoning, which are among the provinces with less than 1 carbon emission efficiency, are all the key areas in the belt and road initiative, and their carbon emission efficiency values have reached 0.75 or above, indicating that most of the key areas in the belt and road initiative have higher carbon emission efficiency than other areas. But at the same time, the belt and road initiative region still has Guangxi, Yunnan, Jilin, Ningxia and other regions ranked behind, indicating that the belt and road initiative still has regions with low agricultural modernization and low carbon emission efficiency. It can also be seen from the table that the input slack variables are all 0 in regions with carbon emission efficiency value of 1, which means that there is no surplus and ineffective input in agriculture in these regions.

4. dynamic evaluation of malumquist lunberger index

Based on Malumquist Luenberger index, this paper makes a dynamic evaluation and analysis on the agricultural panel data of 30 regions in China from 2014 to 2017. The ML index, Tech index and Effch index of 30 regions in the country from 2014 to 2017 were averaged respectively. The calculation results with Deap2.1 software are shown in Table 5 below:
Table 5. The 2014-2017 average ML index and decomposition of 30 regions of the country

| Provinces | ML index | Technological Efficiency Change | Efficiency Change | Provinces | ML index | Technological Efficiency Change | Efficiency Change |
|-----------|----------|----------------------------------|-------------------|-----------|----------|----------------------------------|-------------------|
| Beijing   | 1.053    | 1.053                            | 1                 | Hubei     | 1.102    | 1.035                            | 1.064             |
| Tianjin   | 1.03     | 1                                | 1.03              | Hunan     | 1.071    | 1.026                            | 1.044             |
| Hebei     | 1.061    | 1.05                              | 1.11              | Guangdong | 1.106    | 1.069                            | 1.035             |
| Shanxi    | 1.159    | 1.098                            | 1.056             | Guangxi   | 1.038    | 1.036                            | 1.002             |
| Neimeng   | 1.025    | 1.025                            | 1                 | Hainan    | 1.024    | 1.03                             | 0.994             |
| Liaoning  | 0.975    | 0.998                            | 0.997             | Chongqing | 1.116    | 1.073                            | 1.04              |
| Jilin     | 1.01     | 1.007                            | 1.003             | Sichuan   | 1.08     | 1.014                            | 1.065             |
| Heilongjiang | 1.051   | 1.012                            | 1.039             | Guizhou   | 1.271    | 1.135                            | 1.12              |
| Shanghai  | 0.914    | 0.914                            | 1                 | Yunnan    | 1.018    | 1.069                            | 0.952             |
| Jiangsu   | 1.077    | 1.037                            | 1.038             | Shanxi    | 1.037    | 1.069                            | 0.969             |
| Zhejiang  | 1.066    | 1.013                            | 1.052             | Gansu     | 1.037    | 1.043                            | 0.994             |
| Anhui     | 1.055    | 0.999                            | 1.056             | Qinghai   | 1.126    | 1.126                            | 1                 |
| Fujian    | 1.109    | 1.109                            | 1                 | Ningxia   | 1.054    | 1.066                            | 0.989             |
| Jiangxi   | 1.11     | 1.053                            | 1.054             | Xinjiang  | 1.02     | 1.018                            | 1.002             |
| Shandong  | 1.015    | 0.998                            | 1.028             | National  | 1.059    | 1.039                            | 1.02              |
| Henan     | 1.018    | 1.019                            | 0.999             | B&R       | 1.042    | 1.045                            | 0.998             |

Since the Belt and Road Strategy was released in September and October 2013, the average level of agricultural carbon emission efficiency in the 17 regions where it is located is 1.042, which is greater than 1, indicating that the overall agricultural carbon emission efficiency in the region is on the rise. This also reflects that under the Belt and Road Strategy, China's input agricultural production factors have promoted the improvement of agricultural carbon emission efficiency and effectively controlled agricultural carbon emissions. It can be seen from Table 4-1 that 13 of the 30 regions in the country are higher than the national average, and there are 5 provinces in the region where the Belt and Road Strategy is located.

Table 6. Decomposition of agricultural carbon emission efficiency in the Belt and Road region

| Year | Efficiency index | 2015 | Tech index | 2016 | 2017 |
|------|------------------|------|------------|------|------|
| 2015 | 1.056            | 0.962| 1.047      | 0.978|      |
| 2016 | 1.024            | 1.064| 1.047      |      |      |
| 2017 |                  |      |            |      |      |

Table 6, it can be seen that from 2014 to 2017, the average the belt and road initiative Regional Progress Index (tech) was 1.045 and the average effch index (EFCH) was 0.998, which shows that in recent years, production technology has been continuously improving while technology management is relatively limited. Since the promulgation of the Belt and Road Strategy, the trend has remained relatively stable except for the great fluctuation from 2015 to 2016. Among them, before 2016, a significant decrease in the technical efficiency index leads to a decrease in the carbon emission efficiency. After 2016, the fluctuation direction of the technical progress index and the carbon emission efficiency index is more consistent, and the technical efficiency index remains relatively stable.

5. Conclusion

A) According to the calculation results of carbon emissions, the national average carbon emissions is 5.0883 million tons, and the average carbon emissions in the belt and road initiative area is 4.439 million tons, which is lower than the national average carbon emissions and 15 provinces and cities are below the average. Among them, the key delineated areas in the belt and road initiative account for
10, accounting for 10/15=66.67%, and the belt and road initiative area accounts for 17/30=56.67% of the statistical provinces. For provinces with low carbon emission efficiency, agricultural resources should be utilized efficiently, and measures should be taken according to local conditions. For example, Yunnan Province can take measures such as afforestation. Inner Mongolia should use its grassland advantages to convert farmland to grass. From the analysis of the data in the table, it can be seen that animal husbandry and planting activities have become the two major sources of carbon emissions. Therefore, we should optimize the layout of agricultural industry, reduce the abuse of chemical fertilizers and optimize its structure, improve the efficient waste disposal technology, and attach importance to the green development of animal husbandry.

B) According to the static evaluation of the super-efficiency SBM model, in 2017, 5 of the 17 selected key areas in the belt and road initiative achieved a carbon emission efficiency value of 1, and the agricultural input, expected output and unexpected output were effective and accounted for slightly more than 30 provinces and cities. Among the provinces and cities with carbon emission efficiency values lower than 1, the top 6 regions are all key regions in the belt and road initiative, with efficiency values of 0.75 and above. Therefore, the carbon emission efficiency in the belt and road initiative region is higher than that in other regions.

C) From the dynamic evaluation of ML index, the average carbon emission efficiency in key areas delineated by the "one belt and one road" strategy is 1.042, with the average progress index (tech) being 1.045 and the average technical efficiency index (effch) being 0.998. According to specific data, among the 13 provinces that are higher than the national average agricultural carbon emission efficiency level, 5 provinces are located in the region where the Belt and Road Strategy is located, accounting for a relatively large proportion. Technological progress is the main reason to promote the improvement of agricultural carbon emission efficiency, while the impact of technological efficiency on agricultural carbon emission efficiency is relatively weak, so agricultural technology and agricultural modernization should be strengthened.

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