Analysis on input-output efficiency of renewable resources industry in Hubei Based on DEA-Malmquist model

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Abstract. Recycling of renewable resources is an important way to promote economic green, cycle and low-carbon development, and to build a resource-saving and environment-friendly society. In order to improve the input-output efficiency of renewable resources industry in Hubei Province and realize the effective allocation and scale benefit of renewable resources, this paper selects five input-output indicators, including fixed assets stock, annual average number of employees, number of enterprises, total industrial output value and total profit volume of discarded resources comprehensive utilization industry. Then we use DEA-Malmquist index model to calculate the input-output efficiency of the renewable resources industry in Hubei province from 2009 to 2016. According to the result, we explore the changing trend of production efficiency and the reasons of its change. The conclusion can provide reference for relevant departments to propose strategies for improving efficiency and promoting industrial development.

1. Introduction
Hubei is an old industrial base. The key pillar industries are steel, automobile, and photoelectric and so on. In recent years, with the rapid development of industry, the scrapped volume of scrap cars, scrap tires, scrap steel and waste electronic equipment has increased significantly, which has caused serious pollution to the environment. As a solution to many problems, such as resource exhaustion, energy shortage, and environmental pollution and so on, the renewable resources industry has emerged and has been developed rapidly.

In 1987, the National Economic Commission jointly issued the "Circular on the further development and utilization of renewable resources" and first proposed "renewable resources"[1]. In the "renewable resources management" which promulgated by the Ministry of Commerce, renewable resources are clearly defined. They are waste materials which don’t have the original value when are produced in the production and consumption, but after recovery, classification and processing, they can be obtained the new value [2]. Renewable resources include scrap metals, scrap electronic products, scrapped electromechanical equipment and parts, waste paper materials (such as waste paper, waste cotton, etc.), light chemical raw materials (such as rubber, plastic, pesticide packaging, animal bones, hair, etc.) and waste glass and so on.
With the development of the renewable resources industry, many scholars have studied it. Foreign research on renewable resources industry mainly focus on the research and empirical analysis of the regenerated resources industry system, Kroon et al. [3] had researched on the recycling logistics network system of reusable packaging box, and applied in Holland. Di Vita G, Islam M Ro Islam M Ra et al. [4, 5] research on the technology substitution rate between renewable resources and natural resources and the technology development and application process from the perspective of technology.

In order to promote the development of renewable resources industry, many domestic experts and scholars mainly research the development status and development system of renewable resources industry, analyze its recovery mode, and put forward to promote the overall level of renewable resources industry promotion proposal. Such as Changchun Zhou, Huijuan Feng and Feiffer Zhang et al. [6, 7] analyze the current development of renewable resources, recycling industry model and the existing problems. Jayce CAI Et Al. [8] compare the development of renewable resources industry at home and abroad, and then combined with the overseas development experience, put forward the corresponding measures on issues related to the renewable resources industry in china.

In addition, the existing literature mainly focused on the technical efficiency of manufacturing, agriculture, finance, high-tech industry and cultural industry. Caves R. and Burton D [9] measured the manufacturing technology efficiency of American states from 1959 to 1972 by using stochastic frontier method, and analyzed the reasons. Lynda and Richmond [10] used the DEA model to analyze the changes of manufacturing productivity and efficiency in the UK from 1966 to 1990.

However, there are few literatures on the input-output efficiency of the renewable resources industry. Some scholars have done some research on the recycling economy's efficiency. Such as Lebo Wu and Yang Zhou [11] selected gross value of industrial output, energy consumption and industrial workers as input indicators, selected the industrial "three wastes" emissions as output indicators, then applied the dynamic DEA to study on the development efficiency of recycle economy of the provinces in China. Yongjian Up et al. [12, 13] used the Malmquist index method and the panel data from 2005 to 2012 to estimate the total factor productivity of the renewable resources industry of 21 provinces and cities in China.

From the above documents, we see that there are two methods to research the total factor productivity (TFP): one is stochastic frontier approach (SFA); another is the data envelopment analysis method (DEA) proposed by Chimes in 1978. According to table 1, the DEA method has more flexibility.

| The type of comparison | SFA | DEA |
|-----------------------|-----|-----|
| Choice of production form | Applicable to single output, multi-input efficiency estimation | Applicable to the estimation of the technical efficiency of multiple inputs and outputs |
| Production front surface determination | Need to make assumptions about the exact form of the function and the distribution of the error terms | Don't need to make assumptions |

Therefore, this paper adopts DEA method to measure the input-output efficiency of the renewable resources industry in Hubei province.

2. The framework of the model

2.1. DEA method
The basic model of DEA (CCR) [14] is expressed as: suppose there is No decision making unit, namely for $DMU_j, j = 1, 2, ..., n$, the corresponding input and output combination of $DMU_j$ is $(x_{ij}, y_j)$. Each $DMU$ has M type input and S type output, there are $x_i = (x_{1j}, x_{2j}, ..., x_{mj})$. Thus if $j_0 \in (1, 2, ..., n)$, for a
selected $DMU_{0}$, can be used to determine the relative effectiveness of CCR model with dual non-Archimedes infinitesimal judgment. This paper uses equivalent linear programming model of Charnels-Cooper transformation:

$$
\min V_{D_e} = [\theta - \epsilon (\hat{\epsilon}^T S^- + \hat{\epsilon}^T S^+)] \\
\sum_{j=1}^{n} x_j \lambda_j + s^- = \theta x_0 \\
\sum_{j=1}^{n} y_j \lambda_j - s^+ = y_0 \\
\lambda_j \geq 0, j = 1, 2, ..., n \\
s^- \geq 0, s^+ \geq 0
$$  \hspace{1cm} (1)

$\hat{\epsilon}^T = (1, 1, ..., 1) \in E_m, e^T = (1, 1, ..., 1) \in E_S, \epsilon$ is non-Archimedes infinitesimal.

$\lambda_j$ Express ratio combination structure of an effective decision unit $DMU_j$, $\theta$ express radial optimization or "distance" from the effective frontier of $DMU_j$. If the value of $\theta$ is closer to 1, the decision unit is more reasonable. $s^-$ And $s^+$ are relaxation variables, they are nonnegative. For the optimal solution of the formula (1), the solution is satisfied:

1. When $\theta = 1$, casino making unit $DMU_j$ are weak DEA efficient;
2. When $\theta = 1$, $d_s = s^+ = 0$, decision making unit $DMU_j$ are DEA efficient;
3. When $\theta < 0$, the decision unit $DMU_j$ are invalid for DEA.

2.2. Malmquist index model

The Malmquist index model is proposed on the basis of the DEA model. It uses the ratio of distance functions to calculate the input-output efficiency. The concrete principles are as follows:

$$
M_{t,c}^{t+1} = TC \cdot EF = PC \cdot SC \cdot EFC \\
M_{t,c}^{t+1} = \frac{d^t_{c}([x^t_i, y^t_i])}{d^t_{c}([x^t_i, y^t_i])} \times \frac{d^t_{c}([x^{t+1}_i, y^{t+1}_i])}{d^t_{c}([x^{t+1}_i, y^{t+1}_i])}
$$  \hspace{1cm} (2)

In the formula (2), $c$ respectively reflect the variable and immutable reward of scale; reflect the total factor productivity change (TFC) during the period of $t$ and $t+1$ under variable reward of scale, it can be decomposed into technological change (TC) and technical efficiency change (EFC). TC can be further decomposed into pure technical efficiency change (PC) and scale efficiency change (SC); $x^t_i, x^{t+1}_i$ represent the input vector of the $i$ DMU in $t$ and $t+1$ respectively; represent the output vector of the $i$ DMU in $t$ and $t+1$ respectively; represent the distance function of the $t$ and $t+1$ production points based on the technical efficiency of the $i$ DMU in the $t$ period.

3. The source of data

The study object of this paper is input-output efficiency of renewable resources industry in Hubei Province, but the industry statistical yearbook no division of renewable resources industry. We select the related industrial waste resources and waste materials recycling industry (renamed the waste resources comprehensive utilization industry in 2011) as the industry data. The sample period selected for this paper is 2009-2016 years. Thus, this paper selects 40 sample values of waste resources comprehensive utilization industry in Hubei Province in the past 2009-2016 years. The data is selected from the 2010-2017 year of the Hubei statistical yearbook.
4. Selection of indicators
The input-output efficiency of the regenerated resources industry is divided into input index and output index.

4.1. Determination of the input index
Industry investment includes a lot, such as capital, labor, services, and other raw materials. According to the characteristics of renewable resources industry, the main inputs are capital and labor.

(1) Capital input (C)
In capital input, the fixed assets are estimated as the capital stock according to the sustainable inventory method which is the mainstream of the academic circle. For the base capital stock, because it is difficult to obtain renewable resources industry data, we use 2009 as the base period, in order to avoid depreciation, the net value of fixed assets in 2009 of renewable resources industry express the stock of fixed assets of the industry in 2009. First, we can obtain annual increment of fixed assets that net fixed assets of this year subtracts the net fixed assets of last year, reduce the specified asset increment of the year according to the price index of investment in fixed assets, and then add to the fixed asset stock of the last year. At last, we can get the fixed asset stock of this year, the formula is:

\[ K_t = K_0 + \sum_{t=0}^{t-1} \frac{\Delta K_t}{P_i(t)} \]  

In the formula, is the net value of fixed assets in 2009; is increase of net value of fixed assets in t year, is investment price index of fixed assets in t year. The annual capital increase and capital stock can be obtained by using this formula

(2) Labor input (L)
In the industrial labor input, it is mainly measured by the number of employees, the time of employment and the wages of the employees. The number of employees is the most commonly measurement index of labor input. Considering the data acquisition, this paper selects the average number of employees which are employed in the comprehensive utilization industry of waste resources as an index to measure the labor input of renewable resources industry.

(3) Service input (S)
Service input is an important index that affects the production efficiency of renewable resources industry. It is mainly used to measure the organizational efficiency of industries. This paper selects the number of renewable resources industrial enterprises to reflect the service input.

4.2. Determination of the output index
For the manufacturing industry, most of them take the total industrial output value and enterprise value or industrial added value as output variables. Considering the quantity of samples, this paper select the total industrial output value and profits of waste comprehensive utilization of resources industry as a measure of renewable resources industry output index. In order to eliminate price factors, the industrial product price index is used to reduce the price, which is based on the constant price on the basis of 2009.

5. Comprehensive evaluation of input-output efficiency of renewable resources industry in Hubei

5.1. Calculation of production efficiency of renewable resources industry in Hubei
Using the DEA model, and applying DEAP software to analyze Table 2. The output oriented DEA algorithm is used to further investigate the situation of variable scale on the basic C2R model, and get the effective results of overall efficiency, pure technical efficiency and scale efficiency. See Table 3.
Table 2. Input and output data of renewable resources industry in Hubei.

| Decision unit (MU) | Stock of fixed assets (10000 Yuan) | Annual average number of employees (0000 persons) | Quantity of enterprises (nit) | Gross output value of industry (00 million Yuan) | Total profit (00 million Yuan) |
|-------------------|-----------------------------------|-----------------------------------------------|-----------------------------|-----------------------------------------------|-------------------------------|
| 2009              | 5.66                              | 0.47                                          | 28                          | 21.51                                         | 1.92                          |
| 2010              | 6.36                              | 0.56                                          | 32                          | 36                                            | 1.98                          |
| 2011              | 7.48                              | 0.54                                          | 22                          | 51.77                                         | 5.12                          |
| 2012              | 7.34                              | 0.61                                          | 28                          | 66.1                                          | 3.05                          |
| 2013              | 9.78                              | 0.69                                          | 40                          | 87.89                                         | 2.895                         |
| 2014              | 12.51                             | 0.77                                          | 51                          | 119.95                                        | 0.85                          |
| 2015              | 24.69                             | 0.85                                          | 61                          | 132.79                                        | 2.17                          |
| 2016              | 33.53                             | 0.93                                          | 69                          | 153.1                                         | 2.69                          |

Table 3. Calculation of production efficiency of renewable resources industry in Hubei.

| Year | Comprehensive technical efficiency | Pure technical efficiency | Scale efficiency | Scale return condition |
|------|-----------------------------------|---------------------------|-----------------|-----------------------|
| 2009 | 0.526                             | 1.0                       | 0.526           | Increasing            |
| 2010 | 0.66                              | 0.898                     | 0.735           | Increasing            |
| 2011 | 1.0                               | 1.0                       | 1.0             | invariant             |
| 2012 | 1.0                               | 1.0                       | 1.0             | invariant             |
| 2013 | 1.0                               | 1.0                       | 1.0             | invariant             |
| 2014 | 1.0                               | 1.0                       | 1.0             | invariant             |
| 2015 | 0.982                             | 0.982                     | 1.0             | invariant             |
| 2016 | 1.0                               | 1.0                       | 1.0             | invariant             |
| Average | 0.896          | 0.985                     | 0.908           |                       |

From the results of Table 3, we can see that after 2011, all the efficiency values are 1, which are DEA effective and are in the best condition. In 2009, the change index of technical efficiency is 1, and there is no room for improvement. The scale efficiency change index is only 0.526. It is at DEA less effective and better than DEA invalid in 2010. From the scale of efficiency, 2009 and 2010 are in the stage of increasing scale, which indicates that the scale of production in the year is small and the scale of production can be expanded to realize scale economy.

5.2. Analysis on the change of total factor productivity in renewable resources industry

Based on Deap2.1 software, the Malmquist production efficiency index of renewable resources industry is calculated, and the change of total factor productivity (TFP) is obtained, as shown in Table 4.

Table 4. Malmquist production efficiency index and decomposition of renewable resources industry in Hubei.

| Year     | Technical efficiency change index | Technical progress index | Pure technical efficiency change index | Scale efficiency change index | Total factor productivity change index |
|----------|-----------------------------------|--------------------------|----------------------------------------|-------------------------------|----------------------------------------|
| 2009-2010| 1                                 | 1.189                    | 1                                      | 1                             | 1.189                                  |
| 2010-2011| 1                                 | 2.272                    | 1                                      | 1                             | 2.272                                  |
| 2011-2012| 1                                 | 0.783                    | 1                                      | 1                             | 0.783                                  |
| 2012-2013| 1                                 | 0.877                    | 1                                      | 1                             | 0.877                                  |
| 2013-2014| 1                                 | 0.521                    | 1                                      | 1                             | 0.521                                  |
| 2014-2015| 1                                 | 1.093                    | 1                                      | 1                             | 1.093                                  |
| 2015-2016| 1                                 | 0.984                    | 1                                      | 1                             | 0.984                                  |
| Average  | 1                                 | 1.005                    | 1                                      | 1                             | 1.005                                  |
Shown from table 4, average TFP growth of renewable resources industry in Hubei is 0.5% during 2009-2016. During this period, Gross output value of industry of renewable resources industry grew from 21.51 billion Yuan to 160.4 billion Yuan, the amount of employees grew from 4700 people to 9300 people, and fixed assets stock grew from 5.66 billion Yuan to 33.53 billion Yuan. This shows that the renewable resources industry in Hubei develops rapidly.

From the results of total factor productivity (TFP), the technical efficiency remained invariant during the study period, and the annual growth rate of technological progress was 0.5%. Therefore, on the whole, the growth of the total factor productivity of renewable resources industry in Hubei is the result of technological progress. Figure 1 can be drawn according to the data of Table 4.

![Figure 1. Total factor productivity trend of renewable resources industry in Hubei from 2009 to 2016](image)

Can be seen from Figure 1, the total factor productivity would fluctuate, it has a sharp increase from 2010 to 2011, and then fell sharply from 2011 to 2012. In the next few years, it has a small growth and downtrend. This shows that productivity growth mechanism of renewable resources industry in Hubei is not stable.

### 6. Conclusion

In this paper, we use DEA model to calculate the input-output efficiency of renewable resources industry in Hubei from 2009 to 2016, and use the Malmquist productivity index model to reveal the changing trend of the renewable resources industry. We can see that the development of renewable resources industry in Hubei has been a general up trend in the past 5 years, and maintain rapid growth. This result is inextricably linked to the emphasis on environmental protection, our country manages the renewable from strengthening top-level design of laws and regulations and guiding the fund system, thus the renewable resources industry has greater development space.

There are also some shortcomings in this study. For example, the selected indicators are inadequacy because of the availability of data. In addition, the Malmquist productivity index method generally requires a long time series of data analysis, because China's renewable resources industry is developed lately and the statistical analysis of the data is less, this paper selects 8 years, the span is relatively short, the results may have certain limitations. In the future we need to carry out further research.

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