Evaluation and Reconstruction of World Food Security System

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Abstract. Recent events have shown that there are big loopholes in the global food system. In order to analyze the pros and cons of the existing model, we have analyzed the evaluation and construction of the food system according to the following logical thinking to highlight the sustainability and fairness of the food security system. Firstly, this thesis uses the Entropy Weighting Method to evaluate, compare and analyze food security in each country, for the convenience of the model, we randomly sampled the top 73 countries in the world’s comprehensive strength rankings and selected 33 samples. According to the four goals we are going to discuss: efficiency, profitability, sustainability, and fairness. 14 specific secondary indicators are selected. Combined with the DEA model, we further scored the preliminary model. Secondly, we select the United States and China as representatives and bring them into the model for calculation. It is found that the improvement of the model makes developed countries no longer have an advantage in comprehensive scores. It can also indicate that in the current food system, developed countries are more concerned about efficiency and profitability, which to some extent leads to weaker sustainability and fairness.

1. Introduction

1.1 Background
The global food system is of great complexity. It has been developing since the beginning of human agriculture. The intensification of globalization has enhanced the degree of worldwide interdependency over the last half century. Due to the growth of population, economy and urbanization, demand for food has risen sharply. A series of problems are emerging in the global food system recently. Many current food systems are unstable because they confront the world with challenges about severe food insecurity and irreversible environmental impacts. Our current food system is not perfect, so it seems that the transformation of the food system is necessary and imminent.

1.2 Purpose
Figure 1 shows the global prevalence of severe food insecurity in the total population. From the distribution, we can see the areas facing the food crisis in recent years are mainly distributed in Asia and Africa, and most countries are showing an upward trend. In order to solve this problem. This thesis put forward the purpose that establish a food system evaluation model, conduct a comprehensive assessment of the current food system. The final result should be reflected in two priorities: high efficiency and high profit.
2 Assumption and Notation

2.1 Assumption
To simplify the problem and focus on the crucial issues, our analysis will be based on the following assumptions. These assumptions are the premise throughout the paper.

(1) Most of the unprocessed data used in the study come from different years, but the time is close.
(2) We assume that the latest indicators in each country are at the current level.
(3) For individual missing values, use the arithmetic mean of the same indicator to fill in.
(4) Temporarily rule out the impact of the new crown epidemic on the world food system.
(5) The impact of each indicator on different countries is similar.

2.2 Notation
Our nomenclature used in this paper are defined in Table 1

| Symbol | Definition |
|--------|------------|
| EWM    | Entropy Weighting Method |
| DEA    | Data Envelopment |
| CCR    | Charnes, Cooper, and Rhodes Model |
3 Analysis

3.1 Evaluation Model Based on EWM-DEA Methodology

3.1.1 Synopsis
Efficiency and profitability are two of the priorities of the current food system, and a comprehensive assessment of this system is an effective way to improve the system. Firstly, build a food security evaluation index system based on the relevant world agriculture data in the Food and Agriculture Organization of the United Nations (FAOSTAT) and World Bank, and use the Entropy Weighting Method to evaluate, compare and analyze food security in each country. Secondly, we use the DEA model to measure the efficiency of food allocation and the level of profitability in selected countries. Finally, we get the total ranking of two methodologies and interpret the results[3].

3.1.2 Solving Process
(1) Improvement of the original evaluation model
The existing models of the evaluation system include the "Report on the State of Food Insecurity in the World 2013: Multiple Dimensions of Food Safety" issued by FAO[4]. This model mainly selects from the four dimensions of food supply, stability, access capacity and utilization level, 30 indicators, established a food safety evaluation indicator system and evaluated the food safety status of 157 countries and regions in the world. However, the existing model is a comprehensive assessment of food safety from the perspective of a complete production chain. It conducts a detailed assessment of the internal food system, but does not explain the external effects of existing food security in the world in all aspects. In order to further evaluate the focus of the existing food system, we directly start with the four aspects of food production efficiency, food profitability, sustainability of production and fairness of food system distribution, establish four subsystems, and then divide them into specific ones. The indicators are measured for each subsystem.

Fig2. Evaluation Model
### Table 2: Individual Indicators of Subsystem

| Subsystem       | Individual Indicators                        | Unit       | Weight  | Entropy  |
|-----------------|----------------------------------------------|------------|---------|----------|
| Efficiency      | Land area equipped for irrigation            | %          | 0.0447  | 0.8503   |
|                 | Average value of food production             | 1$/cap    | 0.0410  | 0.8628   |
|                 | Food production                              | 1000 tonnes | 0.1278  | 0.5725   |
| Profitability   | Cereal import dependency ratio               | %          | 0.0061  | 0.9795   |
|                 | Value of food imports in total exports       | %          | 0.0194  | 0.9352   |
| Sustainability  | Cropland organic soils net stock change      | gigagrams  | 0.0617  | 0.7935   |
|                 | Grain yield per hectare                      | ton/ha    | 0.0593  | 0.8016   |
|                 | Food losses                                  | 1000 tonnes | 0.1427  | 0.5224   |
|                 | Percentage of forest development area        | %          | 0.0815  | 0.7274   |
|                 | Share of total agriculture CO2 emissions     | %          | 0.0659  | 0.0659   |
| Equity          | Agricultural area per capita                 | hectares  | 0.1057  | 0.6464   |
|                 | Population with severe food crisis           | %          | 0.0687  | 0.7701   |
|                 | Protein supply                               | g/capita/day | 0.0102  | 0.9657   |
|                 | Prevalence of undernourishment               | %          | 0.1652  | 0.4474   |

### (2) Construction of Evaluation Model System
The selection of specific indicators for the evaluation model is explained here: Based on the analysis of the objectives of this topic and comprehensive consideration of existing papers and existing data sources, four specific indicators are finally determined. The specific treatment method is as follows:

**Normalization**

For positive indicators:

\[ X_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \]  

(1)

For negative indicators:

\[ X_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \]  

(2)

Calculate the proportion of each indicator \( X_{ij} \) represents the j-th indicator of the i-th country

\[ Y_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}} \]  

(3)

**Calculation of Information Entropy**

\[ e_j = -k \sum_{i=1}^{m} (Y_{ij} \cdot \ln Y_{ij}) \]

\[ k = 1/\ln(n) > 0 \]  

(4)

**Index Weight**

\[ W_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \]

\[ d_j = 1 - e_j \]  

(5)

(3) Evaluation result analysis
According to the above formulas and steps, we use Matlab to calculate the entropy and weight of each specific index based on the entropy weight method, as shown in Table 1.

- **Synthesis of Food Security Index**

After we determine the weight of each indicator, we use the entropy coefficient method to calculate the weight of each indicator. According to the additive properties of entropy, we use the indicator information utility value of the lower structure to determine the weight corresponding to the upper structure in proportion to $W_j$ numerical value. Summing the utility value of each type of index in the lower structure, the utility value of the index in the first volume is obtained, which is recorded as $D_k$ and then the comprehensive evaluation index of food security is obtained:

$$D = \sum_{k=1}^{K} D_k$$ (6)

Here we separately sum up the utility value of each specific small indicator to obtain the weights corresponding to the four major themes, as shown in Table 3 below:

| Subsystem          | Weight |
|--------------------|--------|
| Efficiency         | 0.2559 |
| Profitability      | 0.1754 |
| Sustainability     | 0.2378 |
| Equity             | 0.3309 |

It can be seen from the Table 3 that in terms of the four sub-systems of food security, the fairness sub-system has the greatest weight, followed by efficiency, sustainability and profitability. The rationality of this evaluation system is that fairness is particularly important for today’s world food security system, and this is exactly what the world food system ignores. The current food system often pursues efficiency and profitability. Although the food produced is enough for everyone on the earth, a large number of people are still in hunger. Through the above evaluation model and comprehensive index calculation method, the following specific calculations are made for 33 countries randomly selected from the world comprehensive strength rankings.

(4) **DEA Model**

When calculating the allocation efficiency of the food security system, the selection of input and output indexes is crucial. Based on the EWM, we select 7 inputs $(x_1, \ldots, x_7)$ as the measurement of Equity and Sustainability, and the other 4 outputs $(x_8, \ldots, x_{11})$ as the measurement of Efficiency and Profitability. A CCR Model of DEA that can measure both efficiency and profitability is chosen in this study. We intend to measure 33 countries from various levels of development, that is, 33 countries as the DUMs in our model. The number of DMUs should satisfy the Equation below:

$$n \geq max\{m \times s, 3 \times (m + s)\}$$ (7)

where $m$ is the number of inputs used in this DEA Model, and $s$ is the number of outputs involved.

| Item                                      | symbol |
|-------------------------------------------|--------|
| Cropland organic soils Net stock change   | $x_1$  |
| Share of total CO2 emissions              | $x_2$  |
| Grain yield per hectare                   | $x_3$  |
According to the linear programming technique, the optimal solution can be obtained by substituting the data into the CCR model. If the optimal solution is 1, then the optimal solution is valid, otherwise invalid. DEA Efficiency results from Matlab2020b calculations are shown in the figure 3.

From figure 3, we can see a total of 21 countries have a DEA Efficiency of 1, which means that they are effective systems of high efficiency and profitability. Other countries can also rank by value. The final ranking of the 33 countries is combined with the index of EWM before. By combining the DEA Method with the EWM, the evaluation results are completely from the index value of the evaluation object, without any subjective intervention, the empirical results are objective and true, and the conclusion is basically practical.

Figure 3: DEA Model Output
4. Conclusions
In the whole modeling process, we try to avoid subjective methods and use objective methods to solve all the problems of order and optimization. For example, in the evaluation model, the EWM and the DEA are calculated to obtain the final weight, and the fact is still associated with the data, which is more stable than the subjective assignment method. The optimization model is solved by regression modeling on the basis of evaluation model, and the selected countries are analyzed. Our problem-solving process has always carried out the classification and analysis methods of countries at different levels of development in order to take into account the true effectiveness.

Our data in this paper is all obtained from the official report website, so the accuracy of the model is reliable. At the same time, we conducted a sensitivity analysis of the model to see how our solutions will change under the influence of different parameters, and also proved that our model is stable in some aspects. But we have some weaknesses definitely: Our DEA evaluation model does not reflect the ranking of effective DMUs. Although we combine the analysis by EWM, the ranking may not be accurate because of the different nature of the two methods. The optimization model is based on the linear programming model, which requires a large amount of data. Because of the small number of countries we choose, whether the linear law is well reflected remains to be considered.

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