Research on optimal Modeling of Food system based on data potential Distribution Mining and quantitative Analysis

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Abstract. The current world food system gives priority to efficiency and profitability, creating some environmental and inequality problems in the world. In order to re-optimize our food system, we have developed a food system model to adjust the efficiency, profitability, fairness and sustainability of the food system. First of all, we describe the positive and negative effects of food systems optimized for fairness and sustainability, respectively. We have established the index system, and on the basis of the existing data, we use the grey prediction and fitting method to obtain the future data of each index. After that, we divide the previous 12 indicators into benefit category and cost category, and use entropy method to get the weight of indicators that affect benefit and cost each year. We use the "scale factor" method to quantify indicators that are difficult to measure, build models to calculate cost and benefit priorities for changing the world food system, and chart changes that benefit cost ratios in different years.

Keywords: Food system, Grey prediction, Entropy weight method, The scaling factor, Benefit cost ratio (BCR)

1. Introduction

The global food system is the sum of all the processes and infrastructure involved in feeding the world’s population. Although the global food system is more efficient, it is still chronically unequal in distribution, so that people in some countries and regions suffer from hunger and malnutrition even when enough food is produced to meet the needs of all mankind. Human food production will bring some environmental pressure to the earth, because food production will bring some environmental damage to land, fresh water, forest resources, etc. Population growth, climate change, increasing natural disasters and other factors also make the world face more severe food security challenges [1]. According to relevant studies, if no improvement measures are taken, the impact of human food production on the environment will increase by 50%-90% between 2010 and 2050 [2].
In 2018, scientists established a global food system model to study the impact of food production on the environment, in order to take corresponding measures to reduce the damage of food production on the environment [2]. In 2019, the APEC meeting issued a declaration to promote the construction of a more integrated, intelligent and sustainable food system [3]. Today, the importance and urgency of optimizing and realizing a sustainable global food system have become even more prominent. It is an important global issue facing all mankind.

2. Improving the equity and sustainability of the food system
The existing food system prioritizes its efficiency and profitability, which allows food to be produced and distributed relatively cheaply and efficiently. But a food system that prioritises efficiency and profitability inevitably has some problems with uneven distribution. In order to optimize the existing food system, we have adjusted and improved the system with the goal of improving the equity and sustainability of the food system. The following is the specific process of optimization and modeling.

2.1. Possible outcomes of optimizing the equity and sustainability
Today's world food system prioritizes efficiency and profitability over equity and sustainability, with the result that the food system is increasingly polluting the environment and increasing food insecurity. According to statistics, at least 820 million people around the world face hunger, and a large proportion are undernourished. In response, we must pay attention to the equity and sustainability of the food system. So, what happens if the food system is optimized for equity and sustainability? We explain the positive and negative effects respectively:

Positive effects:
Reducing stress on the environment caused by the food system: a focus on the sustainability of the food system will inevitably reduce the consumption of natural resources, and the waste produced by agriculture will decrease or increase at a slower rate.
Fewer hungry/undernourished people: In a context of equity and sustainability, food distribution and food waste will be addressed, food distribution will be more equitable, and quality food will be more available to the undernourished.
Increased infrastructure: transportation and related infrastructure will be improved in order to get food everywhere, which will effectively solve the "last kilometer" problem of food distribution.

Negative effects:
Increased costs of the food system: to achieve equity and sustainability, increased financial and material resources are required, and inevitably, to some extent, the efficiency and profitability of the system will be reduced.

Some countries or regions need large-scale reform of their food systems: the reality is different in different countries, and if the focus of the food system is changed, some countries and regions will face a long and complex reform effort.

2.2. Determine food system index values
First of all, we defined four first-level indicators in the food system according to the value of the food system, and determined the second-level indicators under each first-level indicator by referring to relevant materials. The four first-level indicators are efficiency, profitability, equity and sustainability. Figure 1 shows the display of various indexes of the food system.

Efficiency. Efficiency refers mainly to the efficiency of the production and circulation of the food system. According to Song Liang’s study on the circulation efficiency of major grain producing areas [4], production efficiency is closely related to the power of agricultural machinery, the number of labor forces and infrastructure. Therefore, we take $T_{11}, T_{12}$ and $T_{13}$ as the three secondary indexes to measure efficiency.

Profitability. Profitability mainly refers to the profit level of food circulation transactions in the food system. Since earnings are greatly affected by transaction price, transaction quantity and agricultural added value, we take indexes $T_{21}, T_{22}$ and $T_{23}$ as the three secondary indexes to measure the profitability level.

Equity. Equity mainly refers to the ability and level of the food system to equitably share the output results with people all over the world. According to data, regions with a low per capita GDP, a high proportion of poor people and a high frequency of food insecurity are prone to unfair food distribution. Therefore, we take $T_{31}, T_{32}$ and $T_{33}$ as the three second-level indicators to measure equity.

Sustainability. Sustainability refers primarily to the ability of the food system to maintain its effective functioning over the long term. According to the research report of FAO and other relevant authoritative literature on the sustainability of food system [5] [6], we know that the sustainability of food system is related to the resources, pollution and the proportion of undernourished population in the food system. Therefore, we take $T_{41}, T_{42}$ and $T_{43}$ as the three second-level indicators to measure sustainability.

2.3. Calculate index weight with Entropy weight method
We used the entropy weight method to calculate the weight of each index, and the relevant data came from the FAO and the World Bank [7]. Then, the entropy weight of each first-level index in the food system can be obtained as follows:

$$W_1 = 0.295, W_2 = 0.317, W_3 = 0.184, W_4 = 0.204$$

From the calculation results of entropy weight above, we can see that $W_1 + W_2 = 0.612$ and $W_3 + W_4 = 0.388$, indicating that the global food system has given priority to its efficiency and profitability since 2000 to 2018. Among them, the entropy weight of $W_2$ is the largest, that is, the profitability of the food system is the highest priority. So what the world food system is paying most attention to is its profitability, and then its efficiency, which is in line with the reality.

2.4. The different between optimized system and the existing system
We predicted many future values of the 12 indicators by means of grey prediction and fitting, and made some corrections to them. Here, we used the predicted data to conduct our analysis.
In order to observe the changes of each index before and after the optimization of the food system more intuitively, we normalized the values of each index and normalized them to the interval \([1,2]\). Finally, we drew the radar chart as shown in Figure 2 in which numbers 1 to 12 respectively represented 12 second-level indicators of the food system from \(T_{11}\) to \(T_{43}\).

By figure 2 we can see intuitively, as the world’s food system priority by the efficiency and profitability into equity, sustainability, the general changes of various indexes between is: after 2027 years of agricultural machinery, infrastructure, trade, food price index, global grain markets, serious/moderate food safety and agricultural nitrous oxide emissions were more than 2017, and a few other indexes fell.

**Overall change**

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**Figure 2.** Landmark map for each indicator

**Figure 3.** Changes in the proportion of the world's poor
Analysis of individual index changes

The above is the general situation of the change of indicators. Next, we choose $T_{32}$, the proportion of poor population, a key indicator of fairness, for detailed analysis: Poverty is one of the most acute social problems in the world. The higher the proportion of poor people, the more vulnerable the region is to the inequities of the food system. Figure 3 shows the change chart of the proportion of the world's poor population obtained through grey prediction. From the figure, we can see that the proportion of the world's poor population has been declining, but the rate of decline is different in different stages.

We can roughly divide the 50 years from 2000 to 2050 into three phases:

Stage 1: Around 2000-2013. The proportion of people living in poverty has dropped significantly. This is due to the steady growth of the international economic situation during this period. The international community has made poverty eradication a top strategic goal of international development, and countries around the world have also carried out in-depth poverty alleviation reforms [8].

Stage 2: Around 2013-2019. The rate of decline in the proportion of people living in poverty has slowed significantly, which has much to do with the world food system's emphasis on efficiency and profitability over equity.

Stage 3: Around 2019-2050. The rate of decline in poverty is significantly higher than in the second phase, which we believe is due to the changing priorities of the world food system. It should be pointed out that as early as 2018, scientists pointed out the shortcomings of the world food system and emphasized the importance of optimizing it. Therefore, as shown in Figure 3-3, the accelerated decline in the proportion of the world's poor population from 2019 is consistent with the reality. Encouragingly, according to our projections, the proportion of the world's poor will fall to less than 1% by 2050.

Figure 4. Forecast agricultural value-added as a percentage of GDP after 2019

3. Forecast the implementation time of the system

We use grey prediction and fitting method to predict the subsequent index value. For the data of curve change, we use the method of grey prediction to predict its future value. For the straight line data, we use the fitting method.

Grey prediction

After grayscale prediction, our fitting expression is as follows:

$$y = 233.137 - 228.281 \cdot \exp(-0.020134 \cdot t)$$
Through calculation, we can get our accuracy level \( c = 0.1126 \), which is within a good range of the accuracy level. Then, the residuals, relative errors and grade-ratio deviations are calculated respectively, and the results show that they are all within the acceptable range.

The prediction results of \( T_{23} \) using the grey prediction method are shown in Figure 4.

**Fitting method**

The index of \( T_{11} \), namely agricultural machinery, was fitted by MATLAB, and the fitting expression was obtained as follows:

\[
Y = 388865.944 * t - 751867317
\]

Its fitting image is shown in Figure 5:

**Figure 5.** Agricultural machinery index fitting

As can be seen from Figure 5, the expression has a good goodness of fit, so we can predict the agricultural machinery index after 2019.

**Figure 6.** The benefit and cost of the optimized food system
4. Benefits and costs of changing priorities

Scaling factor method to measure the benefits and costs of changing food system priorities, we first identified indicators that affect costs and benefits. Referring to the index values of the food system determined before, \( T_{11}, T_{13}, T_{21}, T_{22}, T_{23} \) and \( T_{31} \) were determined as indexes to measure the benefit of the food system, and \( T_{12}, T_{32}, T_{33}, T_{41}, T_{42} \) and \( T_{43} \) were determined as indexes to measure the cost of the food system.

What we intuitively get is the change in the value of each indicator, which is measured either in numbers or in percentages. It is difficult to directly measure them in money and link them with economic quantities such as costs and benefits. Therefore, we propose a method of scale factor to quantify it indirectly.

We note that \( T_{31}, GDP \) per capita, is a good indicator for directly quantifying benefits. Moreover, this index is significantly different between developed countries and developing countries, which is convenient for our future research on developed countries and developing countries. We assign the weight of \( GDP \) per capita as the scaling factor, and \( GDP \) per capita per year as the value of the standard scaling factor, which is \( GNP \).

We use the scaling factor method to calculate the \( BCR \). We can well measure the cost-benefit relationship of the food system under different circumstances of changing the food system priority. The results calculated according to the above formula are drawn as Figure 6:

As can be seen from Figure 6, the benefits and costs of the optimized food system begin to increase significantly around 2027 and reach the maximum in 2029. Based on the model and data, we can reasonably infer that in order to make equity and sustainability the priority of the global food system, a large amount of continuous investment is needed, which will inevitably lead to the increase of the cost and benefit of the system at the same time, but the cost still slightly exceeds the benefit. This investment peaks in 2029, and the cumulative effect of the money is driving the transformation of the food system. After the transition is basically over in 2029, funding will gradually decline each year until it returns to normal levels.

5. Time when benefits and costs are incurred

Here, we define the time at which the costs and benefits of the food system change their priorities: it is the point at which the \( BCR \) begins to change from greater than one to less than one. Therefore, with equity and sustainability as priorities, we draw a graph of \( BCR \) changes over time, as shown in Figure 7. In the figure, the blue line represents the \( BCR \) change curve of the optimized grain system, the
red line represents the base line when the $BCR$ is equal to 1, and the intersection point of the blue line and the red line is the situation where the system cost is equal to the benefit.

As can be seen from Figure 4-2, $BCR = 1$ around 2027 means that the benefit and cost of a food system with equity and sustainability as its priority will change around 2027. This timing is consistent with the results of our first question, which suggests that the world food system will achieve a shift in priorities around 2027. Based on the model and data, it is reasonable to assume that in order to promote the equitable and sustainable development of the world food system, a large amount of capital will be invested and the benefit cost of the world food system will therefore change from $BCR>1$ to $BCR<1$.

With the passage of time, the $BCR$ curve began to rise, indicating that with the continuous improvement of the food system, its benefits and costs began to balance, and the improvement funds invested played a good role.

6. Conclusion
In this paper, we have mainly carried out the following two aspects of work.

(1) We describe the positive and negative impacts of food systems optimized for equity and sustainability respectively. To assess how different the changed food system will be from today's, we have listed four food system priorities and a total of 12 indicators that affect each priority; Based on the existing data, the grey prediction and fitting method is used to obtain the future data of each index. According to the obtained data, we explain the changes of most indicators of the optimization system, and focus on the analysis of the difference between the "proportion of poor population" and the current index, and use the entropy weight method to determine the influence weight of each index in different years. We define the time when the sum of the weights of indicators affecting efficiency and profitability is less than the sum of the weights of indicators affecting equity and sustainable development, i.e., the time when food system priorities change. According to the analysis, the world food system priorities will change around 2027.

(2) We divide the previous 12 indicators into benefit type and cost type, and use the entropy weight method to get the weight of the indicators that affect benefit and cost respectively in each year. We have tried a "scale factor" approach to quantify indicators that are difficult to measure directly in monetary terms, derived a formula for calculating the costs and benefits of changing world food system priorities, and charted the changes in the benefit to cost ratio ($BCR$) over different years. We find that the relationship between the benefits and costs of the world food system changes around 2027. Finally, we calculate and compare the difference of costs and benefits between developed and developing countries by means of cost-benefit model.

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