Research on the Re-Optimizing Food Systems

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Abstract. Because the current food system prioritizes efficiency and profitability without considering equity and sustainability, the system is already very unstable. Therefore, we put forward optimization policies without changing the free market, and based on this, we established the food system evaluation model, the food system optimization model, and the time prediction model. We use data to analyze major issues and estimate the benefits of these policies. Because the current food system prioritizes efficiency and profitability without considering equity and sustainability, the system is already very unstable. Therefore, we put forward optimization policies without changing the free market, and based on this, we established the food system evaluation model, the food system optimization model, and the time prediction model. We use data to analyze major issues and estimate the benefits of these policies. We use the R language to perform correlation analysis on factors that may affect the food system. Then we use principal component analysis and factor analysis to find direct connections between different variables and establish comprehensive indicators to evaluate the food system. We evaluate from the perspectives of market, industrial foundation, technology, and adjustment capabilities, and analyze changes in the food system through changes in indicators related to equity and sustainability. Then we establish the SI model to estimate the time required to implement the system.

Keywords: Principal component analysis; system optimization; comprehensive evaluation; time prediction.

1. Introduction

1.1. Background

Currently, our global food system is not stable. In the past fifty years, the efficiency and profitability of the food system has been greatly improved. But in the long run, it still cannot meet people's growing needs. Even in wealthy countries, there are food shortages. In addition, the current global food system is not sustainable. It can be said that the current food system is a major culprit of local and global environmental damage. It exacerbates climate change, loss of biodiversity, and consumes a lot of fresh water. According to research, under the current food system, for every dollar spent on food, society will pay two dollars in health, environmental and economic costs. Therefore, re-optimizing the food system is a necessary effort. Our work as Figure 1:

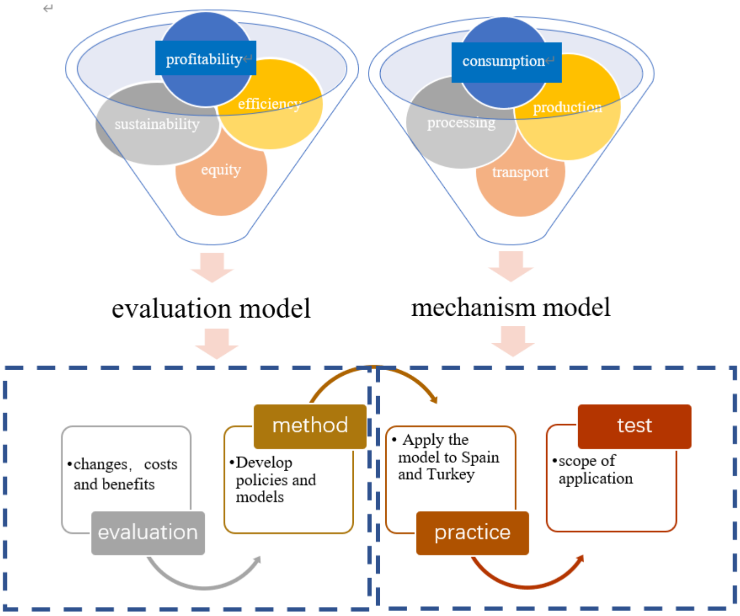

Figure 1. Our work.

2. Assumption and symbol definitions

2.1. Assumption

1) Do not consider the generation of new science and technology, only consider the promotion of existing technology.

2) Replace the output of food with the output of staple food.

3) Food price elasticity is constant.

4) It is believed that every time an advertisement is promoted, waste will be reduced by a certain percentage.

5) The cost of popularizing technology is much lower than the output value of cultivated land, so the cost of popularizing technology is replaced by the reduction of cultivated land value.

2.2. Symbol definitions

In the paper, we use some symbol for constructing the model as follows Table 1:

Table 1. Symbol for constructing the model.

Symbol	Definition
$\mathbf{V_1}$	Per capita arable land area
$\mathbf{v_2}$	Cultivated land output level
$\mathbf{v_3}$	Food miles
$\mathbf{v_4}$	Carbon emission
$\mathbf{v_5}$	Fresh water consumption
$\mathbf{v_6}$	Food demand
$\mathbf{v_7}$	Biodiversity
$\mathbf{v_8}$	Economic benefit
$\mathbf{v_9}$	Comprehensive control ability
N	Total population in the area
I	Number of unaware
R	Number of people promoted every day
S	Number of insiders
$\boldsymbol{\beta}$	Promotion rate

3. Food system evaluation model

3.1. Analysis

Perform correlation analysis on 9 impact indicators of the food system: V_1—V_9. We obtain the following correlation matrix and draw the correlation coefficient graph. It can be seen from the correlation matrix and the correlation coefficient graph that, for example, the correlation coefficients between V_1andV_2, $V_2$and V_6 are all greater than 0.8, indicating that the correlation between the two is relatively high. However, since the correlation coefficients of V_3andV_7, V_3 and V_9 are all less than 0.2, the correlation between the two is low. Due to the different relationships among the 9 influencing factors, principal component analysis is more appropriate.

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Importance of components:
                          Comp.1    Comp.2     Comp.3     Comp.4      Comp.5      Comp.6      Comp.7
Standard deviation     2.6260618 1.1461886 0.63367261 0.59504122 0.126503675 0.109200216 0.069150165
Proportion of Variance 0.7662445 0.1459720 0.04461566 0.03934156 0.001778131 0.001324965 0.000531305
Cumulative Proportion  0.7662445 0.9122165 0.95683219 0.99617375 0.997951878 0.999276843 0.999808148
                             Comp.8       Comp.9
Standard deviation     0.0396123510 1.255108e-02
Proportion of Variance 0.0001743487 1.750329e-05
Cumulative Proportion  0.9999824967 1.000000e+00
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Figure 2. The 9 basic variables.

As can be seen from the Figure 2, there are 9 basic variables, so there are at most 9 principal components in this data set. From the ratio of variance, we know that the first principal component can represent 76.6% of the original data, the second principal component can represent 14.6% of the data, and the third and fourth items can represent 4.5% and 3.9% of the data respectively. As the serial number increases, the ability to express the original data will become weaker. From the ratio of variance, we know that the first principal component can represent 76.6% of the original data, the second principal component can represent 14.6% of the data, and the third and fourth items can represent 4.5% and 3.9% of the data respectively. As the serial number increases, the ability to express the original data will become weaker.

According to the contribution rate of variance accumulation, the contribution rate of the first three principal components has reached 95.7%. After adding the fourth principal component, the contribution rate can reach 99.6%, so we extract the first three or four principal components to explain most of the data, so that we can easily achieve dimensionality reduction. In order to further determine the optimal number of principal components, we draw a scree plot:

When using the scree plot to determine the number of selected principal components, the principal components with a vertical axis variance greater than 0.95 are generally selected. The number of principal components is also selected according to the cumulative contribution rate. It can be seen that the eigenvalue of the image at the fourth principal component is less than 0.95, which is not suitable for the principal component. Therefore, combining the accumulation contribution rate and the information of the gravel map shows that it is reasonable to select three principal components for analysis in this model. We use feature vectors to obtain three principal component expressions:

$$Z_1 = -0.45V_1 + 0.52V_2 \ldots - 0.75V_8 - 0.37V_9 \tag{1}$$

$$Z_2 = -0.88V_1 + 0.82V_2 \ldots - 0.35V_8 - 0.38V_9 \tag{2}$$

$$Z_3 = +0.23V_2 + 0.62V_3 \ldots + 0.56V_8 + 5.46V_9 \tag{3}$$

At the same time, we get the contribution rate of three principal component indicators from Table 2:

Table 2. Three principal component indicators.

Principal component $\mathbf{Z_i}$	The contribute rate $\mathbf{r_i}$
$\mathbf{Z_1}$	40.8%
$\mathbf{Z_2}$	39.2%
$\mathbf{Z_3}$	11.4%

Finally, we get the comprehensive indicator expression:

$$W = r_1 Z_1 + r_2 Z_2 + r_3 Z_3 \tag{4}$$

Bring the equations of Z_1, Z_2, Z_3 into the expression to obtain the evaluation index of the final food system evaluation model.

3.2. Optimize equity and sustainability

Food miles: The distance between consumer food consumption and the origin of food. It reflects the economic, health and quality costs of food in the transportation process, as shown in Figure 3. Healthy diets: Healthy diets have an optimal caloric intake and consist largely of a diversity of plant-based foods, low amounts of animal source foods, contain unsaturated rather than saturated fats, and limited amounts of refined grains, highly processed foods and added sugars.

	Macronutrient intake grams per day (possible range)	Caloric intake kcal per day
Whole grains Rice, wheat, corn and other	232	811
Tubers or starchy vegetables Potatoes and cassava	50 (0–100)	39
Vegetables All vegetables	300 (200–600)	78
Fruits All fruits	200 (100–300)	126
Dairy foods Whole milk or equivalents	250 (0–500)	153
Protein sources		
Beef, lamb and pork	14 (0–28)	30
Chicken and other poultry	29 (0–58)	62
Eggs	13 (0–25)	19
Fish	28 (0–100)	40
Legumes	75 (0–100)	284
Nuts	50 (0–75)	291
Added fats		
Unsaturated oils	40 (20–80)	354
Saturated oils	11.8 (0-11.8)	96
Added sugars All sugars	31 (0–31)	120

Figure 3. The specific configuration.

Equity: Anyone can eat a healthy meal at any time. Sustainability: The core of sustainable development is the coordination of resource protection and environmental protection.

3.3. Policies and results

When optimizing the equity of the food system, based on the interpretation of equity, starting from the indicators of healthy diets, the following two policies are proposed: Adjust the diet. The scientific indicators of healthy diets are formulated with reference to food, dietary patterns, and health outcomes. According to the form of healthy diets, while referring to the characteristics of the region, the government adjusts, supplies, and evenly distributes the food needed to ensure that everyone is likely to have a healthy diet. Increase the promotion of healthy diets. Improve information dissemination and food marketing, and invest in public health information services and sustainable education. Launch dietary guidelines based on specific ingredients. Provide dietary advice and interventions through healthcare facilities.

3.4. Sustainability

When optimizing the sustainability of the food system, based on the indicators of sustainable food production, the following two policies are proposed: Improve food production methods. The current global food system needs a new agricultural revolution, which is built on the basis of enhanced sustainability and driven by sustainability and system innovation. Significantly improve the efficiency of fertilizer and water use, recycle agricultural phosphorus, and redistribute the use of nitrogen and phosphorus worldwide. Take climate mitigation measures (such as changes to crop and feed management) and promote biodiversity within the agricultural system.

Reduce food loss and waste. Reducing losses on the food production side and reducing waste on the consumption side in a sustainable way is a necessary condition for the optimization and sustainability of the global food system. It is necessary to adopt technical solutions in the food supply chain, and it is also inseparable from the implementation of public policies. The areas that should be improved include post-harvest infrastructure, food transportation, processing and packaging techniques, coordination of all links in the supply chain, manufacturer training and equipment, and consumer education.

3.5. Results

After optimizing equity and sustainability, the food system predicts the following results: After the concept of healthy diet has been widely popularized, switching from current dietary patterns to healthy diets is expected to bring significant health benefits. About 11 million deaths are prevented each year, accounting for 19%-24% of total adult deaths. Food loss and waste are reduced by half, in line with the sustainable development goals, and healthy diets are promoted. Using the 2010 value as the base, the estimated changes in food production from 2010 to 2050, divided into normal (BAU) with full waste, the planetary health diet with full waste, and the planetary health diet with halve waste scenario.

Technological progress, improved environment, reduced carbon emissions. Grain production increased, and at the same time, in terms of profit, short-term economic benefits decreased and long-term increased. It can be seen that when optimizing equity, the corresponding indicators of per capita arable land area, cultivated land output level, food demand, economic benefit, and comprehensive control ability will change. Compared with the original system that prioritizes efficiency and profitability, the efficiency and profitability of the system after optimizing equity will be reduced, and the amount of food production and food demand will be increased.

When optimizing sustainability, the corresponding food miles, carbon emission, fresh water consumption, biodiversity, economic benefit, and comprehensive control ability indicators will change. Compared with the original system that prioritizes efficiency and profitability, the efficiency and profitability of the system after optimizing sustainability will be reduced. At the same time, carbon emissions and freshwater consumption have been reduced, and biodiversity has become more abundant. In short, the efficiency and profitability of the system will decrease in both cases. Therefore, it can be concluded that when optimizing the equity and sustainability of the food system, the efficiency and profitability of the system will decrease.

4. The benefits and costs

4.1. The benefits

The food system is divided into four links: production, processing, transport, and consumption. From the perspective of equity and sustainability, after considering changing the priorities of the system, the benefits obtained and the links where the benefits occur are as follows: When optimizing equity, the government will give discounts to the poor and government subsidies, thereby inspiring the poor to buy. This measure has increased the demand for food by the poor, thereby increasing the profitability of the market. Since the purchase occurs in the consumption link of the food system, it is concluded that the income occurs in the consumption link.

When optimizing equity, food consumption and waste are reduced, thereby retaining the value created by part of the food that should be consumed. Therefore, relatively speaking, more benefits are obtained. In the produce process, consciously reduce the amount of food produced. In the consumption link, reduce the amount of unnecessary food purchased. Therefore, it is concluded that the benefits occur in the production and consumption links. When optimizing sustainability, while the total grain output remains unchanged, after returning farmland to forests, the funds for optimizing the ecosystem are equivalent to the costs of the previous part of the grain. The source of the costs is in the production link, so the costs occur in the production link.

4.2. The costs

Similarly, after dividing the food system into four links and optimizing them, the cost consumed and the link in which the cost occurred are as follows: When optimizing equity, it is known from the policy that the government will intervene in the market and issue subsidies. This measure has the potential to reduce market efficiency, and the market generates costs. Since the market is affected in the consumption link, it is concluded that the costs occur in the consumption link.

When optimizing equity, a certain amount of money needs to be invested in the media and other channels to promote the concept of healthy diets. The money spent is the cost of the measure. Because the funds are invested in the final consumption link, it is concluded that the costs occur in the consumption link.

When optimizing sustainability and shortening transportation distances, in order to obtain sufficient food for the region, technological upgrading measures will be adopted to assist regions with underdeveloped production. The funds consumed for technological upgrading are the costs incurred after shortening the food mileage. In the process of food production and processing, technology upgrades may be implemented. Therefore, the cost occurs in the production and processing links. When optimizing sustainability, while the total grain output remains unchanged, after returning farmland to forests, the funds for optimizing the ecosystem are equivalent to the costs of the previous part of the grain. The source of the costs is in the production link, so the costs occur in the production link.

4.3. Difference between developed and developing countries

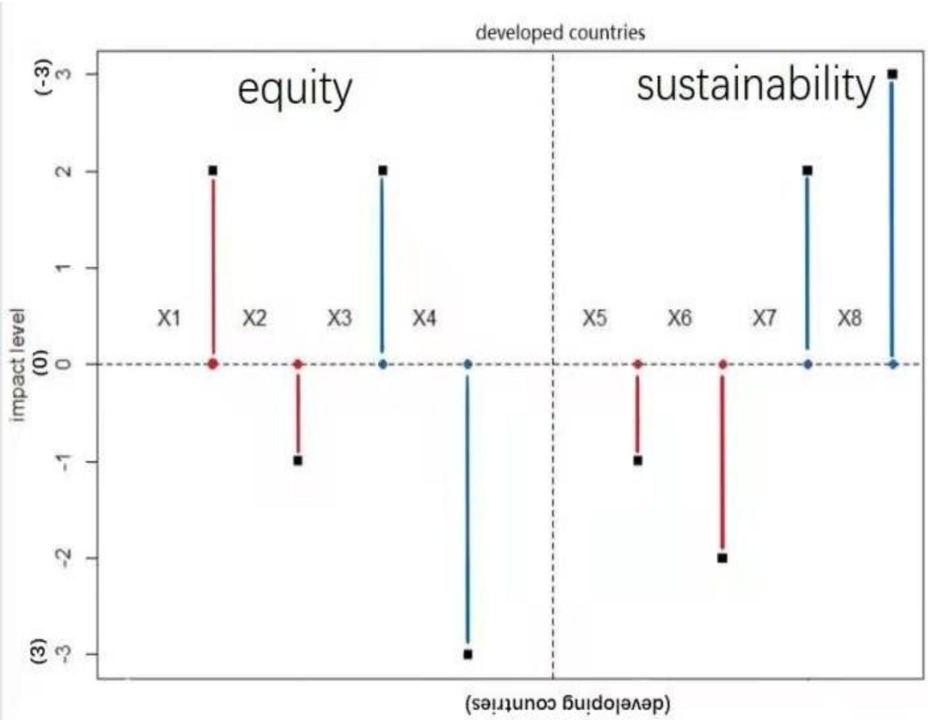

Figure 4. The 8 benefits and costs.

As shown in the figure 4 above, the 8 benefits and costs are represented by $X_1 - X_8$, where red represents benefits and blue represents costs. The benefits and costs are divided into equity policies and sustainable policies. The scale on the left side of the figure is a double scale standard, which represents developed countries in the positive direction and developing countries in the reverse direction. It reflects the extent of the impact of this cost and benefit on developed or developing countries. 3 is the highest, -3 is the lowest, in descending order. Therefore, we can analyze from the figure that X_1 has an impact level of 2 in developed countries and -2 in developing countries. That is to say, the implementation of equity policy makes this benefit have a greater impact in developed countries and less in developing countries. X_7 has an impact level of 2 in developed countries and -2 in developing countries. That is to say, the implementation of sustainability policies makes this cost more influential in developed countries and less in developing countries. The analysis of other X_i is similar.

It can be concluded that, compared with developing countries, implementing equity policies in developed countries will bring more obvious benefits and lower costs. If a sustainable policy is to be implemented, it will bring insignificant benefits and larger costs.

5. Food system optimization model

Measure the profit brought by the optimization policy proposed above, and gets the best profit combination of each policy. The profit reflects the funds allocated in the policy to determine how the policy guides the system to optimize, and then the food system optimization model is derived. The total profits after system the profits after reducing food waste, and the profits after the government implements discounts for the poor.

Optimization equity and sustainability are divided into three parts: the profits after technological upgrades, under the circumstance that the total output remains unchanged, after the technology is upgraded, implement the conversion of farmland to forest to protect the environment. The value of food lost due to returning farmland to forests is regarded as the cost of upgrading technology. The cost of environmental governance reduced by returning farmland to forest is regarded as the total income. The total revenue minus the cost is the profit after upgrading the technology. The model of the profit brought by the technical upgrade is as follows:

5.1. Model establishment

$$s_1 p_1 = sp \tag{5}$$

$$p_1 = (1 + c)p \tag{6}$$

$$r_1 = \frac{sc(H - p_1)}{1 + c} \tag{7}$$

The SEIR model is established as follows:

$$\frac{dS}{dt} = -\frac{r_1 B_1 IS}{N} - \frac{r_2 B_2 ES}{N} \tag{8}$$

$$\frac{dE}{dt} = \frac{r_1 B_1 IS}{N} - aE + \frac{r_2 BES}{N} \tag{9}$$

$$\frac{dI}{dt} = aE - yI \tag{10}$$

$$\frac{dR}{dt} = yI \tag{11}$$

According to the model, the time to achieve the effect in a certain population area is as follows:

It can be seen from the figure that when the desired publicity effect is achieved and food waste is reduced, the time is about 60 days. Estimate the cost during this period. During this period of time, the benefits of saving food that should have been consumed minus the cost are the profits after reducing waste. For the profit brought by reducing food waste, the model is as follows:

$$r_2 = 30\%\beta\gamma - ed \tag{12}$$

According to the government's discount to the poor, establish a non-linear relationship, find a reasonable discount plan, and determine the best profit. The model of the profit brought by the government after discounting is as follows:

$$r_3 = \frac{bR}{a} x\%\beta[(1 - x\%) \times 200\% + 1] - (x\%\beta - \alpha)R \quad (13)$$

Then the profit after optimizing the system is:

$$r = r_1 + r_2 + r_3 \quad (14)$$

The total profit is the sum of the maximum profit brought about by the three policies. The profit is the total profit that can be obtained after the optimization of the food system, which reflects the funds that should be invested in each policy.

5.2. Model application

We have selected the developed country Spain and the developing country Turkey with the same latitude and similar longitude to ensure that the climate and conditions of the cultivated land are basically the same, and the agricultural conditions are basically similar.

5.3. Applied to developed country—Spain

Based on the Internet and data calculated through models, we found that Spain’s poverty alleviation wage standards have exceeded the definition of equity, so equity policies are not applicable in Spain, and we only need to consider the impact of sustainability policies. After looking up the data, after formula calculation, we come to the following conclusions:

1) It is more appropriate to invest in technical levels to increase unit output by 6.3%. When the unit output exceeds 6.3%, it will cause excessive conversion of farmland to forests and insufficient grain output.

2) Spain's income through sustainability policies is about 470 million yuan, the initial investment cost is about 240 million yuan, and the profit gained is about 225.7 million yuan.

It can be concluded that the equity of the food system is not a very important issue in developed countries. The basic living problems of the population in developed countries have been guaranteed to a certain extent, so the equity policy does not have a deep impact in developed countries. Technology has a certain impact on developed countries, so the funds from developed countries to transform food systems are invested in the promotion and upgrading of technology. This conclusion supports the point we made earlier.

5.4. Applied to developing country—Turkey

Substituting the data found on the Internet into the formula, it is found that when the equity policy is implemented: when the government gives the poor a discount, the maximum benefit is when the discount is 40%, and the gain is 240 million yuan. The profit from the promotion of a healthy diet is 20 million. When the sustainability policy is implemented, the maximum profit is when unit output increases by 29%, which is about 38.6 billion yuan. Therefore, we come to the conclusion that equity will affect some profitability in developing countries, and lower costs will lead to higher returns. However, if funding conflicts, it is recommended to invest in the promotion, research and development of technology, there will be greater benefits. This conclusion supports the point we made earlier.

6. The scalability and adaptability

6.1. Scalability

The applicable fields of the model are divided into five levels, namely international, national, regional, community and family.

We evaluate the scope of application based on the optimization plan proposed in the model, the required financial resources and administrative capacity. We find that in terms of equity, the administrative capacity at the regional level is limited, and it is impossible to actively intervene in the market. When it comes to the community and family level, due to the decline in the ability to promote technology, it is impossible to implement policies to ensure sustainability. Reasonable publicity is extremely effective at any level, so our model can give full play to its performance at a larger level, that is, a level above the national level. However, at smaller levels, some functional failures will occur, but it still has a certain degree of scalability.

6.2. Adaptability

1) The model is suitable for countries that have land for their own food production, and countries that basically rely on imported food to supply their own food needs do not apply this model. Generally speaking, it is to ensure the integrity of the food system, and the production, processing, transportation, and consumption links must at least reach the level of normal operation.

2) The country intends to make adjustments in the direction of the food system, that is, there will be a budget for adjusting the food system.

3) The country is in a stable state, and the government manages it. The government can guide the people to a certain extent.

If any of the above points are not met, this model is not applicable. Except for this situation, the model can play a certain role.

7. Conclusions

7.1. Strength

1) In the model, environmental factors and unit output are considered, and it is accurate.

2) Modeling based on the proposed suggestions is feasible.

3) Establish relationships with multiple elements, and the system is more stable and closer to reality.

7.2. Weakness

When building the model, the interaction between different policies was not considered.

Without considering the loss of market efficiency.

If multiple sets of data are fitted multiple times, distortion will appear.

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