Evaluation of Food Security Influencing Factors Based on Entropy Method

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Abstract. To explore the question of the impact of government policies on hunger, we built the Entropy Method Model based on the evaluations, quantifying policies and benefits. Taking into account the diversity of policies and benefits, we have established a systematic evaluation system and calculated the impact capacity of multiple factors. For the actual country, the applicability of the model is verified, and the calculation results of the model in different regions are compared.

Keywords: Freshwater use, Nitrogen application, Phophorus application.

1. Introduction

Food is an important factor in the reproduction of the human world and social development.[1, 2] Due to the differences in the level of development of countries and regions, their ability to ensure food security and rational distribution varies.[3]

Meanwhile, 821 million people in the world still suffer from hunger. [4]The inadequate supply of food has become an obstacle to local health and economic development. In particular, this effect is particularly evident in developing countries.[5] All these circumstances prove that the current global food system needs to be improved urgently.

We build models using different policy normalization matrices and considering their influencing factors. Univariate analysis was used to assess the ability of different factors to improve hunger. In addition, we use the model to analyze hunger and the impact of different national policies on society. Finally, we offer some advice to nations. The model building process is shown in Figure 1:

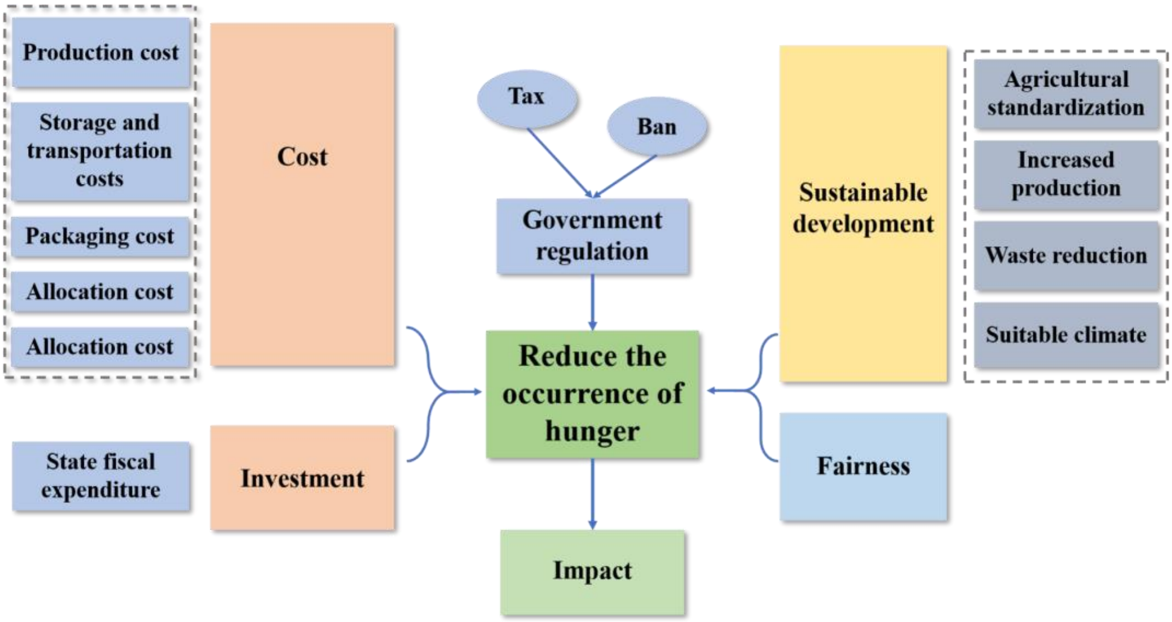

Figure 1. Flow Chart

2. Data Preparation

2.1. General Assumptions

In order to simplify the problem, we made the following assumptions and gave corresponding proofs:

Assumption 1: Carbon emissions will not have an immediate impact on agricultural production.

Justification: Carbon emissions have a profound impact on the global climate and the growth of crops. [6] Although the changes in a year are limited, they will have a cumulative effect. The model assumes that climate change will not change food production and processing methods on a large scale. We only regard climate change as a factor affecting future sustainable development.

Assumption 2: During the research period, there were no technological breakthroughs in food, and external conditions remained unchanged.

Justification: The model is to solve the global hunger problem at this stage. When the external conditions remain unchanged, the prediction of the future is of guiding significance.

2.2. Data Collection

The data we obtain mainly include population data, grain storage and transportation data, carbon emissions data etc. The data comes from large-scale data websites, and the content is highly credible. Table 1 summarizes some sources.

Table 1. Data source

Database	Websites
Our World in Data	https://ourworldindata.org
FAO	http://www.fao.org/home/en/
Google Scholar	https://scholar.google.com/
Frontiers	https://www.frontiersin.org/

2.3. Data Analysis

The data we obtain is based on the year. When collecting different data from different websites, there will be data missing or insufficient data samples. For the problem of missing data, we will take the average of the two adjacent data of the missing year data as the missing year data. If the missing data is greater than two, the data will be ignored in the model calculation. In the case of a small number of data samples, we will shorten the period of forecasting the future accordingly.

3. Entropy Method Model

The entropy method model can systematically reflect the degree of influence of different factors on the system, and finally get the final overall evaluation. When we need to measure the impact of major factors on the system, we must also consider other secondary factors. We can modify the weight of the factors, and then affect the overall evaluation of the system. In this way, the overall evaluation status of the system under different conditions can be obtained.

3.1. Model Building

3.1.1. Data Standardization

In the model, we gave a total of three evaluation indicators, namely: the reduction of malnutrition rate D_1; the reduction of carbon emissions D_2; the reduction of fiscal expenditures D_3. In addition, we give four implementation policies. It is equivalent to four evaluation objects, namely: use of new energy M_1; low-carbon diet M_2; increased food production M_3; mechanized production M_4. We denote the magnitude of the evaluation index D_j of the evaluation target M_i as x_{ij}. The following matrix can be obtained:

$$\begin{pmatrix} x_{11} & x_{12} & x_{13} \\ x_{21} & x_{22} & x_{23} \\ x_{31} & x_{32} & x_{33} \\ x_{41} & x_{42} & x_{43} \end{pmatrix} \tag{1}$$

Because the evaluation indicators are displayed in a percentage system, it is difficult to display the overall situation of the evaluation object. If some important evaluation indicators are not empowered, the evaluation results will be meaningless. First, we normalize the evaluation value. After normalization, the larger the value, the higher the evaluation. The normalization formula is as follows:

$$Y_{ij} = \frac{x_{ij} - \min(x_i)}{\max(x_i) - \min(x_i)} \quad 0 \le Y_{ij} \le 1 \tag{2}$$

3.1.2. Information Entropy of Each Indicator

First, we need to calculate the feature weight P_{ij} occupied by the *i*-evaluation object under the *j* index.

$$P_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{4} Y_{ij}} \tag{3}$$

Next, the formula for calculating the information entropy value is as follows:

$$E_j = -\frac{1}{\ln 4} \sum_{i=1}^{4} P_{ij} \cdot \ln P_{ij} \tag{4}$$

In the above formula, if $P_{ij} = 0$, we make $\lim_{P_{ij} \to 0} P_{ij} \cdot \ln P_{ij} = 0$.

3.1.3. Determine the Weight of Each Indicator

The priority of each indicator determines the weight of the indicator. Now, we need to determine the weight of D_1, D_2 and D_3.

$$D_j = 1 - E_j \tag{5}$$

$$\omega_j = \frac{D_j}{\sum_{j=1}^{3} D_j} \tag{6}$$

3.2. Result

After the weighted value of each evaluation index is calculated, the comprehensive evaluation value of the evaluation object can be calculated. The accurate value of the comprehensive evaluation value provides a reference for decision-making. The formula for calculating the comprehensive evaluation value is as follows:

$$Z_i = \sum_{j=1}^{3} \omega_j P_{ij} \tag{7}$$

The higher the Z_i value, the more the policy meets our required goals.

4. Case Analysis

4.1. Which Policy Is Implemented

We need to extend the model to a developing country and a developed country to verify the generality of the model. We select India and the United States as the tar-get countries for our analysis. According to statistics, food waste in the United States mainly occurs at the consumer level, that is table waste.[7] India's food shortage problem is mainly due to the huge population base.[8] In addition, the low level of farmland planting mechanization and the messy farmland management are also the reasons for the hunger problem. We use the entropy method to analyze the impact of policies on improving hunger.

$$\begin{cases} \text{USA}\begin{pmatrix} 7 & 9 & 8 \\ 10 & 9 & 8 \\ 5 & 7 & 8 \\ 3 & 3 & 7 \end{pmatrix} \begin{pmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \end{pmatrix} = \begin{pmatrix} 0.79 \\ 0.02 \\ 0.19 \end{pmatrix} \begin{pmatrix} Z_1 \\ Z_2 \\ Z_3 \\ Z_4 \end{pmatrix} = \begin{pmatrix} 7.23 \\ 9.60 \\ 5.61 \\ 3.84 \end{pmatrix} \\ \text{IND}\begin{pmatrix} 6 & 9 & 7 \\ 5 & 8 & 6 \\ 8 & 7 & 7 \\ 9 & 9 & 7 \end{pmatrix} \begin{pmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \end{pmatrix} = \begin{pmatrix} 0.41 \\ 0.17 \\ 0.42 \end{pmatrix} \begin{pmatrix} Z_1 \\ Z_2 \\ Z_3 \\ Z_4 \end{pmatrix} = \begin{pmatrix} 6.93 \\ 5.93 \\ 7.41 \\ 8.16 \end{pmatrix} \end{cases} \tag{8}$$

From the matrix, we can get: the United States is suitable for implementing a low-carbon diet policy; India is suitable for implementing a mechanized production policy.

4.2. The Impact of Policies on Economy

After the United States implemented dietary changes:

United States as HIC (Regions include high-income countries). Due to changes in diet, there are some changes on each item. FLX: energy-balanced varieties of the flexitarian, PSC: pescatarian, VEG: vegetarian, VGN: vegan dietary patterns

Cropland use

Net profit after increasing or decreasing the area of cultivated land:

Without considering the cost of production waste, energy, etc., only the income or loss of cultivated land under the condition of the cost of cultivated land reclamation is considered. However, the economic changes brought about by the expansion of arable land may occupy urban space, or the economic changes brought about by the reduction of arable land if the area of urbanization is to be expanded (Figure 2 [9]).

Global environmental impacts in 2030 by socio-economic development scenario (upper panel) and region (lower panel, for socio-economic scenario SSP2).

Environmental domain	Region	Diet scenario												
		BMK	FLX	PSC	VEG	VGN	ani-25	ani-50	ani-75	ani-100	kcal-25	kcal-50	kcal-75	kcal-100
Cropland use (M km2)	Global	10,251	9,382	9,113	9,252	9,166	10,297	10,133	9,968	9,803	10,163	9,864	9,564	9,265
	HIC	1,636	1,188	1,109	1,130	1,040	1,517	1,398	1,278	1,159	1,600	1,564	1,528	1,492
	UMC	1,563	1,233	1,158	1,198	1,182	1,517	1,471	1,426	1,380	1,503	1,444	1,384	1,325
	LMC	5,444	5,143	5,056	5,056	5,061	5,425	5,407	5,389	5,371	5,257	5,071	4,884	4,697
	LIC	1,695	1,883	1,845	1,922	1,931	1,917	1,928	1,940	1,951	1,885	1,865	1,844	1,824
Freshwater use (km3)	Global	1,506	1,343	1,354	1,388	1,480	1,568	1,629	1,689	1,749	1,476	1,444	1,412	1,379
	HIC	140	123	124	130	141	152	163	175	186	137	134	130	127
	UMC	133	111	113	118	130	143	152	162	171	128	123	117	112
	LMC	1,080	915	920	937	992	1,109	1,139	1,169	1,199	1,056	1,032	1,008	984
	LIC	154	196	199	206	222	167	177	187	197	157	157	158	158
Nitrogen application (GgN)	Global	76,626	58,860	58,284	57,399	57,180	76,181	75,471	74,761	74,051	74,242	71,593	68,944	66,295
	HIC	12,096	7,769	7,141	7,137	6,569	10,949	9,802	8,655	7,508	11,835	11,575	11,314	11,053
	UMC	8,074	5,699	5,321	5,304	5,121	7,638	7,201	6,765	6,329	7,757	7,440	7,123	6,806
	LMC	50,998	40,075	40,558	39,675	40,284	51,897	52,796	53,695	54,594	49,001	47,005	45,008	43,012
	LIC	6,080	5,797	5,717	5,724	5,623	6,292	6,238	6,184	6,131	6,244	6,144	6,043	5,942
Phosphorus application (GgP)	Global	11,985	9,803	9,739	9,577	9,436	11,906	11,787	11,668	11,549	11,612	11,199	10,786	10,373
	HIC	1,901	1,272	1,190	1,197	1,088	1,735	1,570	1,405	1,240	1,864	1,827	1,790	1,752
	UMC	1,609	1,205	1,142	1,135	1,061	1,511	1,413	1,314	1,216	1,539	1,468	1,398	1,327
	LMC	7,692	6,442	6,527	6,364	6,413	7,835	7,977	8,120	8,263	7,398	7,103	6,809	6,515
	LIC	867	948	941	937	925	904	900	896	892	893	878	864	849

Figure 2. The related data

Cost increase:

$$\text{Cost}_{\text{sum}} = \sum_{i=1}^{3} C_i \left(M_{i_{after}} - M_{i_{\text{previous}}} \right) \tag{9}$$

M: The quality of nitrogen fertilizer before and after implementation of the policy.

The cost includes not only the use of water and chemical fertilizers, but also the input of machinery production, etc., but according to the evaluation of the data formulas of representative agricultural production influencing factors, it can be seen that changing the dietary structure has a huge impact on the economy.

After India implemented the mechanized production policy:

Since improving the level of mechanization is related to the specific promulgation and implementation of national policies, the following formula is used to measure the economic benefits of policy implementation. Average cost savings per square kilometer:

$$\text{Benefit} = \frac{\text{Benefit } t_{\text{production}} + \text{Benefit}_{\text{save}} - \text{Cost}_{\text{production}} - \text{Cost}_{\text{technology}}}{S_{\text{area}}} \tag{10}$$

It means "(Production increase benefit + production cost saving-new production cost-technology investment) / new area for implementation of mechanization".

5. Suggestions to Nations

- Create national public-private partnerships [10]

In 2020, we are facing the new crown epidemic and natural disasters. When mankind is solving global problems, unity and cooperation, mutual benefit and win-win is the only way to solve problems. Building a community with a shared future for mankind and striving for the common goal of mankind is the direction of our efforts.

- Change at the root

Table waste is a large part of global food waste. Generally, countries with high levels of economic development tend to waste more. The government must use regulations and campaigns to raise citizens' environmental awareness of conservation. Meanwhile, table waste can be recycled and fed to livestock.[11]

- Develop a national strategy

The country as a whole need to have overall coordination. Food security is about every citizen, and food waste also occurs around everyone. The state must unify grain allocation to ensure sufficient grain in various regions. The country also needs to formulate future development plans to prevent accidents from happening.

6. Conclusions

Based on the above analysis and discussion on the impact of different policies on society, different policies have different impacts on developed or developing countries. Among them, the benefits brought by the policies to the society are large or small. The government needs to consider whether the policy is beneficial and the benefits brought by the policy on the issue of hunger, and guide the implementation of the policy after comprehensive consideration. With the rapid development of technology in modern society, the government should keep pace with the times and adopt optimal strategies to reduce or even eliminate hunger.

References

[1] Wynn A, Wynn M. The effects of food shortage on human reproduction [J]. Nutrition and Health, 1993, 9 (1): 43 - 52.

[2] Popp J, Lakner Z, Harangi-Rakos M, et al. The effect of bioenergy expansion: Food, energy, and environment[J]. Renewable and sustainable energy reviews, 2014, 32: 559 - 578.

[3] Seekell D, Carr J, Dell'Angelo J, et al. Resilience in the global food system [J]. Environmental Research Letters, 2017, 12 (2): 025010.

[4] Barbier E B, Burgess J C. Sustainability and development after COVID-19 [J]. World development, 2020, 135: 105082.

[5] DeRose L, Messer E, Millman S. Who's hungry? and how do we know? Food shortage, poverty, and deprivation [M]. UNU Press, 1998.

[6] Koondhar M A, Udemba E N, Cheng Y, et al. Asymmetric causality among carbon emission from agriculture, energy consumption, fertilizer, and cereal food production–a nonlinear analysis for Pakistan [J]. Sustainable Energy Technologies and Assessments, 2021, 45: 101099.

[7] Birney C I, Franklin K F, Davidson F T, et al. An assessment of individual foodprints attributed to diets and food waste in the United States[J]. Environmental Research Letters, 2017, 12 (10): 105008.

[8] Nath R, Luan Y, Yang W, et al. Changes in arable land demand for food in India and China: A potential threat to food security[J]. Sustainability, 2015, 7 (5): 5371 - 5397.

[9] Springmann M, Wiebe K, Mason-D'Croz D, et al. Health and nutritional aspects of sustainable diet strategies and their association with environmental impacts: a global modelling analysis with country-level detail [J]. The Lancet Planetary Health, 2018, 2 (10): e451 - e461.

[10] Osborne S. Public-private partnerships [M]. London: Routledge, 2000.

[11] Westendorf M L, Pas E W Z, Gordon R. Feeding food or table waste to livestock [J]. The Professional Animal Scientist, 1996, 12 (3): 129 - 137.