Research on Stability of Food System Based on AHP and Gray Correlation Analysis

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Abstract: Even though the world is producing enough food to feed its population, millions of people are still hungry. Since food security was put forward in the 1970s, more and more attention has been paid to it. Countries globally have made positive efforts to ensure food security and achieved certain results. However, food insecurity remains a severe problem in today's world. In order to find the method to solve these problems, we established the index to evaluate the quality of the grain system, that is, the stability of the grain system and built the Stability Index Model (SI). SI contains five dimensions (Di) whose weights are obtained AHP (Analytic Hierarchy Process). SI is a weighted sum of the five dimensions. Secondly, each dimension contains two indexes whose weights are obtained AHP. Di is a weighted sum of the two factors. Then, the gray correlation analysis method was adopted to find the data with the best correlation degree, and the data were used as the values after standardized processing. When we prioritize our food systems, we will prioritize our food systems and judge the advantages and disadvantages of different programs according to SI calculation to get a better optimization and adjustment program. Therefore, our model provides a different view of the problems that exist in the food system.

1. Introduction

At the beginning of 2020, a novel coronavirus (infected with pneumonia) epidemic spread worldwide.[1] After the epidemic outbreak, we believe there will be a severe problem if not dealt with on time [2]: the food problem. Including food shortages and food security, the (experiment) personnel aware of food problems also bring a series of economic,[3] social, and environmental problems in order to improve the system's ability to cope with these problems of grain and the food system gets sustainable development, we have to evaluate the stability of the food system, and by to find some measures to improve the stability.[4]

2. Stability Index Model Based on Analytic Hierarchy Process

Food is the material basis for human survival, and the stability of the food system is the necessary prerequisite for the sustainable and healthy development of human society.[5] Recent events have shown us that the global food system is unstable, and many people worldwide suffer from hunger. However, an amazing fact is that there is sufficient food produced to feed every person in the world. It means that many factors cause the instability of the food system. Therefore, this paper selects the following items as influential indicators: development level, efficiency, sustainability, equality, profitability, and disaster factor.[6]

According to the structure of the Stability Index Model, it can be approximately transformed into the following circuit diagram

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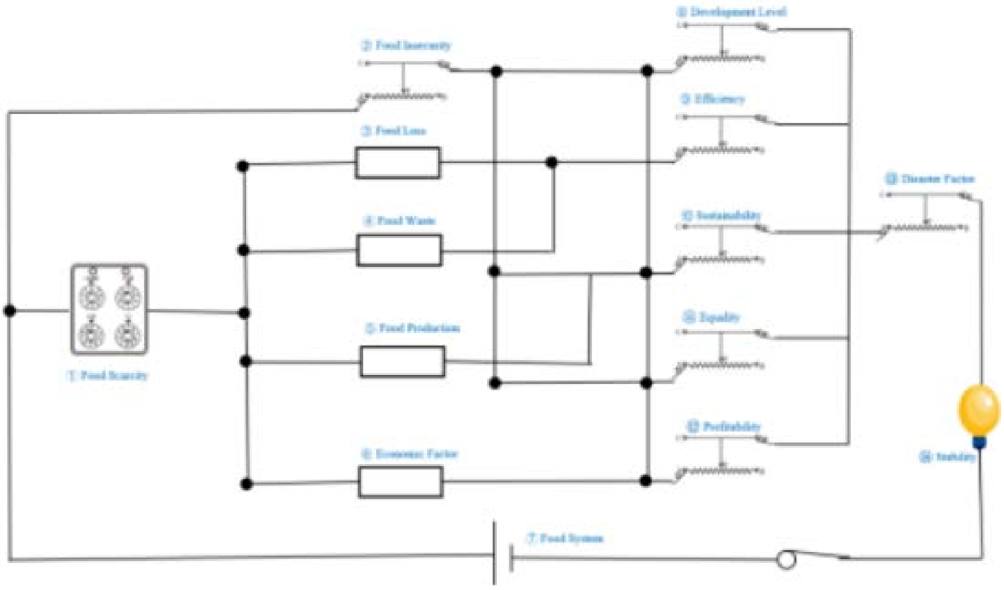

Figure 1. Circuit diagram of food problem

Problems in the Food system can be attributed to Food insecurity and Food shortage, and the influencing factors of Food shortage can be considered as four, namely, Food Loss, Food Waste: Food Production, and Economic Factors. [7]

Food insecurity is related to the level of development, sustainability, and equality, just as electrical components are linked by electricity;

The change of sliding rheostat resistance affects the change of circuit current: just as the change of various influencing factors will cause the change of food insecurity. Parallel branches, etc.

The disaster factor plays a crucial role. Just like the sudden outbreak of the new epidemic in 2020, it exacerbated the food crisis, exerted a considerable impact on the world economy, and brought grave disasters to people all over the world.

The bulb symbolizes the stability of the grain system. The brighter the bulb, the greater the current in the circuit, the smaller the resistance. The grain system analogy: the smaller the effect of the influence factor, the more stable the grain system is.

After carefully analyzing the relevant information, we determine the indicators shown in the figure below:

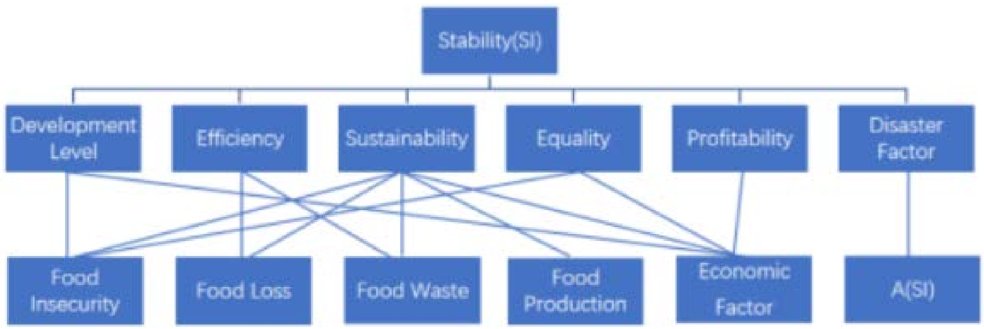

Figure 2. Indicators of Stability Index Model

Because the two factors of Food waste and Food loss are closely related, their proportions vary greatly in different countries, and the relevant data of these two factors are incomplete. However, due to the restrictions of various conditions, their values do not change much within a specific range. Therefore, it is considered that their influence on SI is constant and is set as C1. Similarly, the Economic factor was set to C2.

To calculate the weights of indicators of SI, we intend to use AHP.[8]

Firstly, we define the expressions as follow:

$$SI = \omega_1 DL + \omega_2 EF + \omega_3 S + \omega_4 EQ + \omega_5 P \tag{1}$$

$$DL = \alpha_1 FI + \beta_1 FS \tag{2}$$

Similarly, we have

$$EF = \alpha_2 FI + \beta_2 FS \tag{3}$$

$$S = \alpha_3 FI + \beta_3 FS \tag{4}$$

$$EQ = \alpha_4 FI + \beta_4 FS \tag{5}$$

$$P = \alpha_5 FI + \beta_5 FS \tag{6}$$

Where $\omega_1, \omega_2, \omega_3, \omega_4$ and ω_4 represents the weight of development of the food system (DL), the efficiency of the food system (EF), sustainability of the food system (S), Equality of the food system (EQ), and Profitability of the food system (P) respectively, α_i and β_i represents the weight of the food insecurity indicator (FI) and Food sustainability indicator (FS).

After the analysis of relevant information, and according to the scale table, we construct the score matrices and calculate the weight of each indicator. We construct the judgment matrix and calculate the weight of each indicator:

(1) Construction of judgment matrix A=(aij)n

(2) Normalization of judgment matrix, B=(bij)n, Among them

$$b_{ij} = \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}} \tag{7}$$

(3) Perform consistency checks

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{8}$$

$$CR = \frac{CI}{RI} \tag{9}$$

Where $\lambda_{\max}$ is the maximum eigenvalue of matrix.

Generally, if $CR < 0.1$, the judgment matrix is considered to pass the consistency test; otherwise, it does not have satisfactory consistency.

The judgment matrix needs to be modified.

(4) Calculating weight

$$\omega_i = \frac{1}{n} \sum_{j=1}^{n} \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}} (i = 1,2, \ldots, n) \tag{10}$$

ω_i represent the weight of i_{th} indicator.

In the process of system development, if the trends of two factors are consistent, the degree of synchronous change is high. That is, the degree of correlation between them is high. On the contrary, it is lower. Therefore, the gray correlation analysis method is a method to measure the degree of correlation between factors, which is based on the degree of similarity or difference between the development trends of factors. Namely, the 'gray correlation degree' _There are many factors affecting FI and FS indicators, and many factors are not easily characterized by data or lack of relevant data.

Therefore, we analysed various information and determined the main influencing factors of the FI indicator and FS indicator. For the influencing factors that data cannot characterize, we assume they do not change much within a specific range. Their influence on FI and FS indicators is constant. For the influencing factors that data can characterize, we use the method of gray correlation degree to determine the correlation degree between FI indicator and FS indicator and their related influencing factors, respectively,[9] to represent the development trend of FI indicator and FS indicator with the influencing factor with the most extensive correlation degree.

The specific steps of gray correlation analysis are as follows:[10]

(1) Determine the reference sequence reflecting the behavior characteristics of the system and the comparison sequence affecting the behavior of the system.

For a reference sequence x_0 there are several comparison sequences $\mathrm{X1}, \mathrm{X2} \ldots \mathrm{Xn}$.

Evaluation objects (year) m a day, and the evaluation index has n (factors), the reference number listed as $x_0 = \{x_0 \mid (k), k = 1,2, \ldots, \mathrm{m}\}$, compare several as $x_i \quad = \{x_i(k) \mid k = 1,2, \ldots, \mathrm{m}\}, \mathrm{I} = 1,2, \ldots, \mathrm{n}$

(2) The reference sequence and comparison sequence are dimensionless treated. Due to the different physical meanings of various factors in the system, the dimensionality of data is not necessarily the same, which is not easy to compare, or it is difficult to get the correct conclusion during the comparison.

Therefore, dimensionless data processing is usually required in gray relational degree analysis.

Specific methods: first, the average of every evaluation index, then use the evaluation index of each element is divided by the average, get a dimensionless reference sequence $X_0 = \{X_0\ (k),\ k \mid= 1,2, \ldots, \mathrm{m}\}, \mathrm{n}$ comparison sequence X_i evaluation index of each element is divided into the reference sequence $X_0 = \{X_0\ (k), k \mid= \ = \{X_t(k), k = 1,2, \ldots, \mathrm{m}\}, \mathrm{i} = 1,2, \ldots, \mathrm{n}$.

(3) Calculate the gray correlation coefficient $x_i(k)$ of the reference sequence and comparison sequence

$$\xi_i(k) = \frac{\min\limits_{s}\min\limits_{t}|x_0(t)-x_s(t)|+\rho\max\limits_{s}\max\limits_{t}|x_0(t)-x_s(t)|}{|x_0(k)-x_i(k)|+\rho\max\limits_{s}\max\limits_{t}|x_0(t)-x_s(t)|} \tag{11}$$

Is the correlation coefficient between sequence X_i and reference sequence X_0 on the KTH index, where $\rho \in [0,1]$ is the resolution coefficient, $\min_s \min_t |x_0(t) - x_s(t)|$ and $\max_s \max_t |x_0(t) - x_s(t)|$ are the two-level minimum difference and two-level maximum difference, respectively.

In general, the larger the resolution coefficient ρ, the higher the resolution.

The smaller the resolution factor ρ, the smaller the resolution. For this model, we take $\rho = 0.5$.

(4) Calculate the gray relational degree.

Because the correlation coefficient is the correlation degree value between the comparison sequence and the reference sequence at each moment (i.e., each point in the curve), it has more than one number, and the information is too scattered to facilitate the overall comparison.

Therefore, it is necessary to concentrate the correlation coefficients of each moment (i.e., each point in the curve) into one value, that is, to calculate its average value, which is used as the quantitative representation of the correlation degree between the comparison sequence and the reference sequence. The correlation degree formula is:

$$r_i = \frac{1}{n}\sum\nolimits_{k=1}^{n} \xi_i(k) \tag{12}$$

In the formula, r_i is the gray correlation degree between the comparison sequence X_i and the reference sequence X_0.

The closer r_i value is to 1, the better the correlation is.

(5) Relevance sorting.

Mother will n subsequence of the same sequence correlation in order of size, relational sequence of notes for $r_i\{r_i \mid \mathrm{i} = 1,2, \ldots, \mathrm{m}\}$.

If the value of r_i sequence is the largest: the correlation between the corresponding Ith evaluation index (influence factor) and reflecting system behavior characteristics is much better.

We use the change of cultivated land area to represent the problem of food shortage.

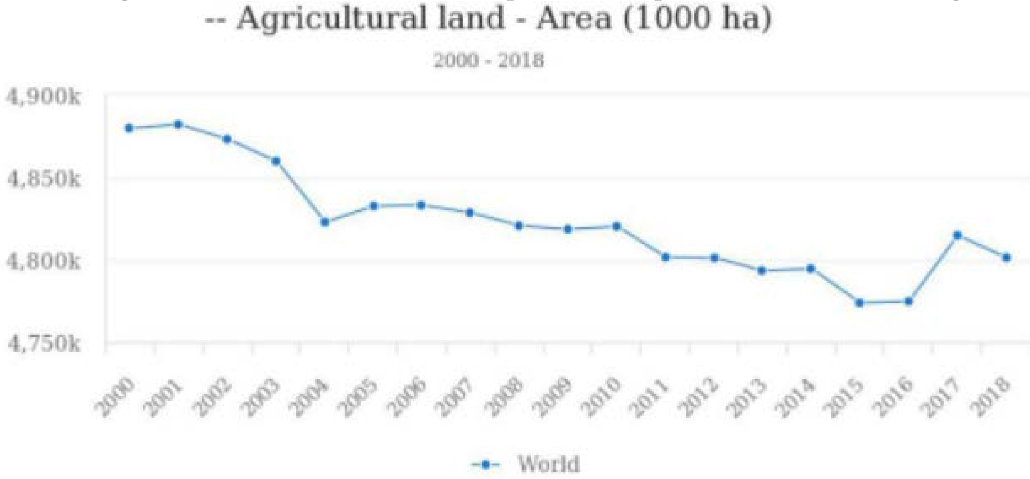

Figure 3. Change of Agricultural land

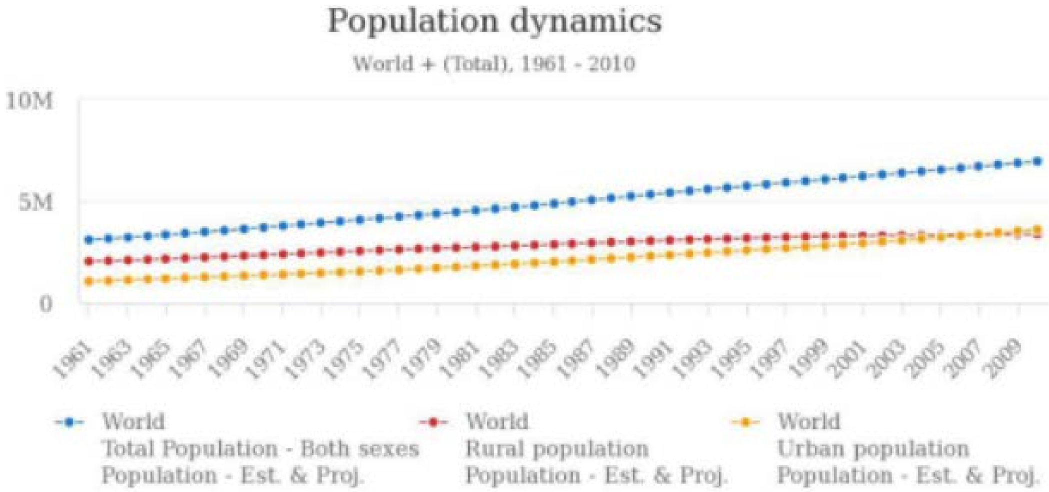

Figure 4. Population Dynamics

Based on the gray correlation analysis method: the main factors affecting FI and FS indicators are obtained, and their change rules represent the changing trend of FI and FS.

Since the units of each factor are different, their values need to be standardized so that the following steps can be carried out. It is the homogenization of heterogeneous indicators.

We defined the standardized data corresponding to the factor $y_{ij}(i = 1,2, \dots, m; j = 1,2, \dots n)$ as $Y_{iJ}(i = 1,2, \dots, m; j = 1,2, \dots n)$ respectively.

$$Y_{ij} = \frac{y_{ij} - \min(y_i)}{\max(y_i) - \min(y_i)} \tag{13}$$

Therefore, the expression for SI is

$$SI = \omega_1(\alpha_1 Y_1 + \beta_1 Y_2) + \omega_2(\alpha_2 Y_1 + \beta_2 Y_2) + \omega_3(\alpha_3 Y_1 + \beta_3 Y_2) + \omega_4(\alpha_4 Y_1 + \beta_4 Y_2) + \omega_5(\alpha_5 Y_1 + \beta_5 Y_2) \tag{14}$$

3. Model Solving

Having established the basic model, we will test it. We selected eight countries at different levels of development to analyze their SI_ In addition, we set a threshold (Thresholds) according to the relevant report. We can see the results in the figure below, which makes comparisons easy.

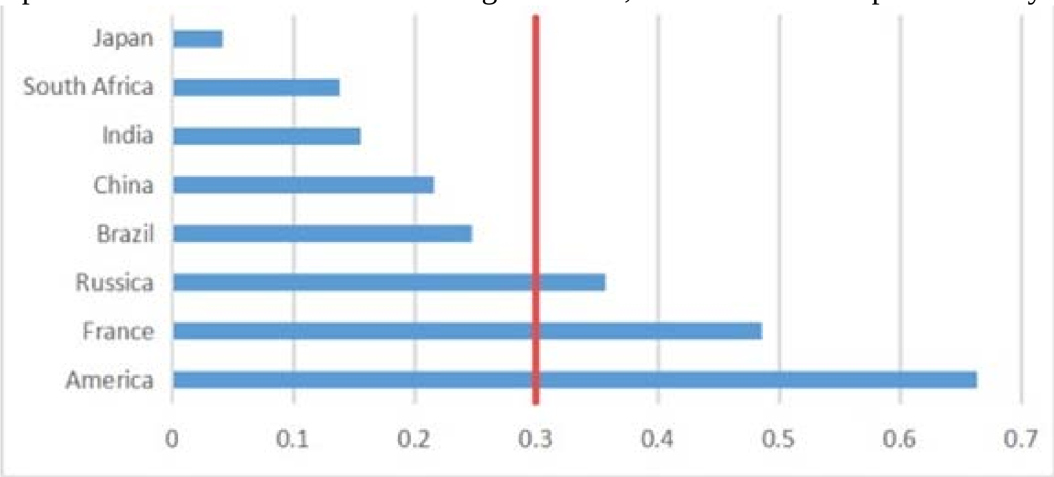

Figure 5. Stable Index (Efficiency and profitability take precedence)

From the picture above, it can be seen when giving priority to efficiency and profitability, with Russia belongs to developing countries, but in terms of the index of food production, in terms of stability index: the index: he had good stability, France, the United States as a representative of the developed countries (except Japan) stability index is bigger, the system stability of grain is big. However, for developing countries represented by South Africa, India, China, and Brazil, the stability coefficient deviates from, and the stability coefficient is small. Although Russia is a developing country, its stability index is relatively high, so its food system is relatively stable. By analyzing the current development status of all countries in the world, it can be seen from the above figure that developed countries have a higher per capita grain output and a more stable food system due to their relatively strong economic development level and scientific and technological strength, as well as a smaller population than developing countries. Japan belongs to the island country. Because of its particular geographical position and topographic conditions, the stability of its food system has a greater impact: which is different from the situation of most developed countries.

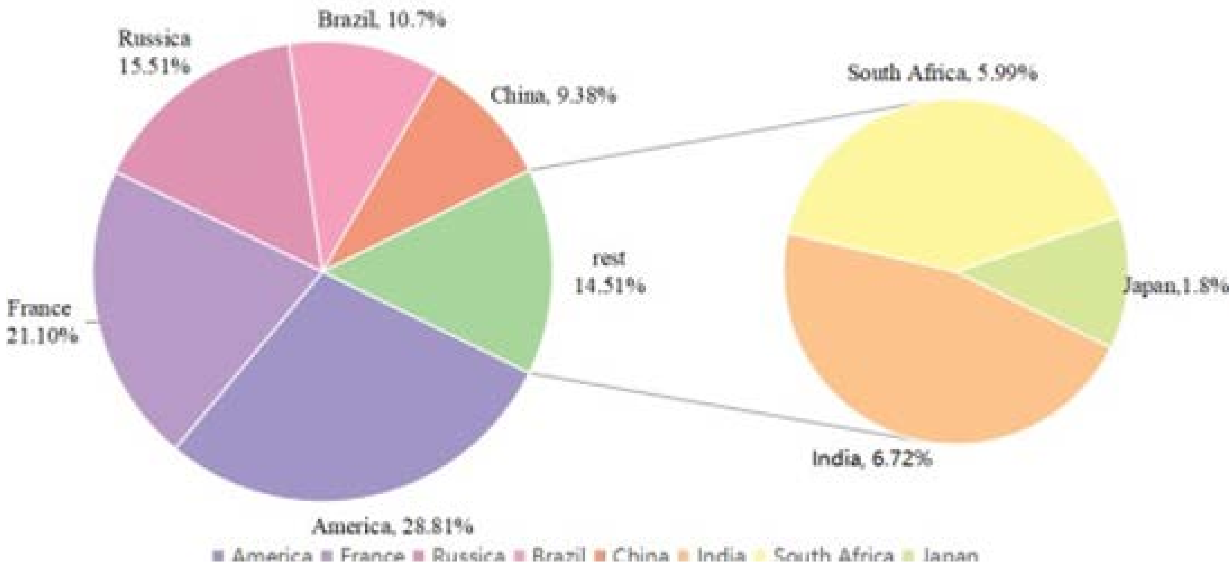

Figure 6. The Proportion of SI Index (Efficiency and profitability take precedence)

From the pie chart above, we can intuitively see the proportion of the SI index of each representative country in the whole. It can be seen from the figure that when interests and efficiency are given priority: the proportion of different countries varies greatly, which indicates that the overall food system of the world is not stable.

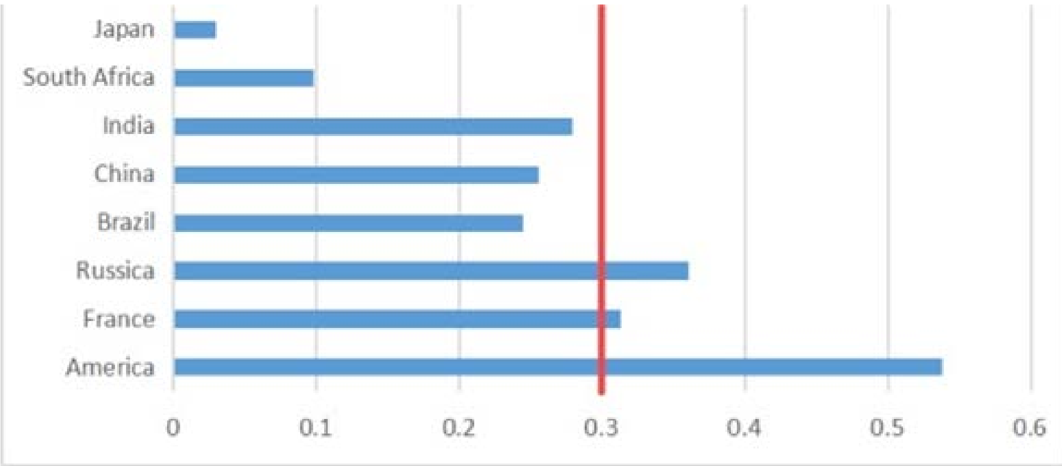

Figure 7. Stable Index (Sustainability and equality take precedence)

It can be seen that when the preferred equity and sustainable development, the developed countries' food system stability index is almost the same. In contrast, developing countries' food system stability index has obvious improvement, gradually close to 0.3. This means that if the preferred equity and sustainable development, then the stability of the food system in developing countries will be significantly enhanced.

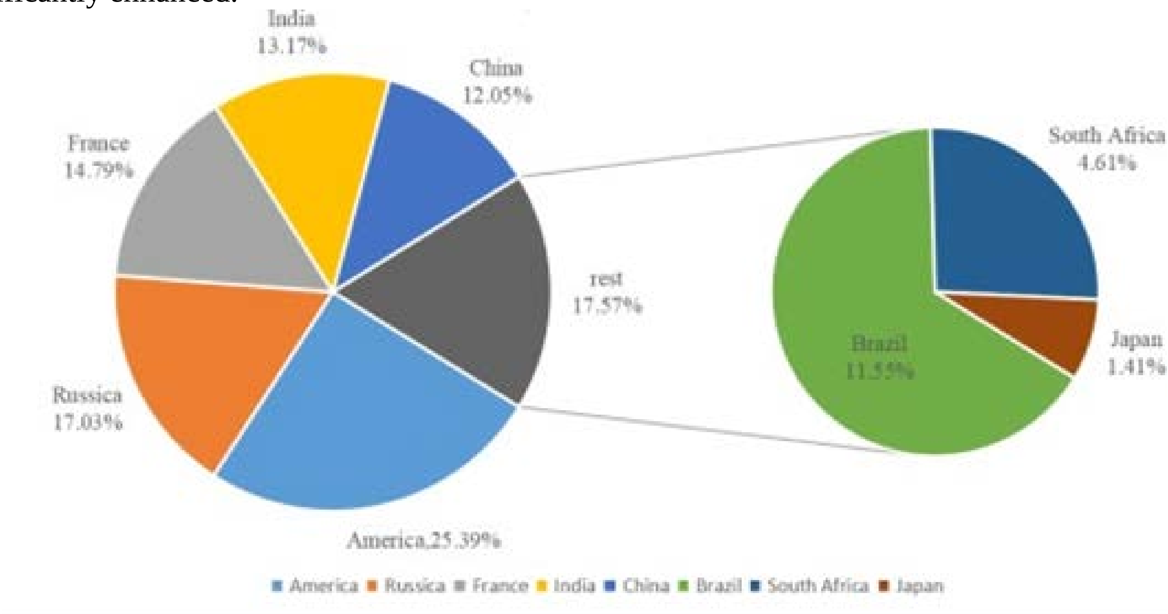

Figure 8 The Proportion of SI Index (Sustainability and equality take precedence)

As can be seen from the pie chart above: when equity and sustainable development are given priority, there is a small difference in the proportion of the SI index of each representative country, on the whole, indicating the stability of the world food system is improved. It can be concluded from the above analysis that: due to the influence of economic development and other factors, the stability of the food system in developing countries differs greatly from that in developed countries_ When the food production and trading system changes its priority factors, the stability of food system will change, and the degree of change in developing countries is more evident than that in developed countries. From the above analysis, it can be concluded that the stability of the grain system in different countries is consistent with the Si obtained by the SI model: which is in line with the objective facts. Therefore, we believe that SI is reasonable.

4. Conclusion

In order to improve the shortage of food, it is necessary to establish an evaluation standard for the quality of the food system. Therefore, we take the stability of the grain system as the evaluation standard and establish an SI model to test the stability of the grain system. This model uses an analytic hierarchy process to measure the weight of each influencing factor to SIZ, and the weight of each index is not fixed. The importance of an index can be adjusted according to the needs to determine the relevant weight: and then change the priority of the system. In order to measure the degree of correlation between an index and influencing factors, we collected a large amount of data. We used the grey correlation analysis method to analyze and calculate to obtain the influencing factors with the greatest degree of correlation with an index. The results are relatively accurate.

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