Research on Global Equity Based on Entropy Weight TOPSIS Model

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Abstract: Our team defines global equity as whether each individual can equally enjoy various resources, including material and non-material resources. We selected 17 indicators from five dimensions: economic, technological, energy, political, and ecological, and used the entropy weight TOPSIS model to score 228 countries and regions at five-time points during 1979-2019. In order to quantify the difference in scores, we refer to and refine the calculation method of the Gini coefficient to derive a Global Equity Index (GEI). We find that the GEI has shown a slight downward trend over the last 40 years.

1. Introduction

For thousands of years, mineral resources have been indispensable to human endeavors,[1] yet they are always limited in time and space compared to the infinite growth of human needs.[2] How can we enjoy the benefits of resource exploitation while ensuring that they benefit every country as equitably as possible?[3] Establishing a model to evaluate global equity will help us have an intuitive understanding of global equity and provide future improvement.[4]

2. Global Equity Evaluation Index System Based on Entropy Weight TOPSIS Model

Our team defines global equity as whether each individual can equally enjoy various resources, both material and immaterial. Based on this definition, in order to analyze the global equity situation, we need to know the access to resources in each country for comparison. Because of this, we refer to TIAN Fujun, ZHENG Yifang [5], and other related documents and select 17 indicators to measure the enjoyment of resources in each country from five dimensions: economic, scientific and technological, energy, political, and ecological.[6]

Most of our data come from major official platforms, including the World Bank and the International Monetary Fund websites. We try most to select first-hand data to ensure the truth and accuracy of the data. However, the data of the same indicator in different platforms may vary, and our criterion is to select the most comprehensive set.

Since the source data has a lot of missing values, we proceed as follows:

1) Keep the reasonable missing value as 0. For example, some countries have no railroad. Some countries have no political power for women, and some countries have no oil fields.

2) Proximity year substitution method. Some years' data are challenging to collect, and the data of left and suitable adjacent years are chosen to supplement.

3) Use the average interpolation method to supplement the data. If the data of the nearby years are also missing, the data of the country available for each year will be filled in after calculating the average value.

4) If the data of a specific indicator for a country are seriously missing and not reasonably available as zero. The data are filled in the world minimum value of the indicator to reduce its interference with the results.

Our team wanted to obtain the most recent data possible, but the data collection found that 2019 data were more comprehensive than 2020 and 2021 while still excluding the impact of Corona Virus

Disease 2019(COVID-19).[7] The lack of data became more severe as time went on, preventing us from measuring earlier scenarios while only advancing to 1979 at ten-year intervals given the number of calculations that could be performed. In addition, data for a few countries were still too severely missing after the first three methods mentioned above, and we had to drop their inclusion in the calculations, finally selecting 228 countries as our evaluation target.

We selected 17 indicators to measure the enjoyment of resources in each country from five dimensions: economy, science and technology, energy, politics, and ecology and chose a suitable method to score each country so that the comparison of different scores can show whether the citizens of each country can enjoy resources moderately.

In selecting the indicators, we referred to a large amount of literature on measuring social equity, and based on the principles of rationality and accessibility, we excluded some reasonable but seriously missing data indicators and finally retained 17 of them. The specific evaluation system is shown in Table 1.

Table 1. Global Justice Evaluation Index System

Indicator Dimension	Indicator Name	Variable	Unit	Resource
Economy	Per capita Gross National Income	X_1	$	World Bank Open Data: World Development Indicators
	Total Railway Kilometers	X_2	Km	
	Per capita Health Expenditure	X_3	$	
	The proportion of Poor People	X_4	%	
	Inflation Rate	X_5	%	
Science and Technology	Science and Technology Budget	X_6	$	World Economic Forum
	Number of Students in Higher Education	X_7	Person	Education statistics-all indicators
	Global Innovation Index (GII)	X_8	/	World Economic Forum
Energy	Per Capita Energy Use (Oil Equivalent)	X_9	Kg	World Economic Forum
	Oil Reserves	X_{10}	Bucket	
	Coal Reserves	X_{11}	Ton	
Politics	GLOBAL PEACE INDEX (GPI)	X_{12}	/	Vision of Humanity
	The proportion of Women in Politics	X_{13}	%	World Bank Open Data: Gender statistics
	Social Stability Index	X_{14}	/	The Global Institute for Peace
Ecology	Per capita Carbon Dioxide Emission	X_{15}	Kg	World Bank Open Data: World Development Indicators
	The Forest Coverage Rate	X_{16}	%	
	Per capita Cultivated Land Area	X_{17}	Hectare	

The core idea is to define the distance between the optimal solution and the worst solution of the decision problem, and finally calculate the relative fit between each solution and the ideal solution to rank the solutions, which is a common decision-making technique for multi-criteria decision analysis of finite solutions [8]. The method has no strict requirements for sample size and data distribution [9]. However, the traditional TOPSIS model relies mainly on expert opinions in determining the index weights, which are highly subjective, and the index weights have a great influence on the final ranking

results. Therefore, to avoid misjudgment caused by subjective factors, the entropy weighting method, an objective assignment method, will be used. In summary, this study will evaluate the global equity level using the entropy weight TOPSIS model with the following steps.

Construct the evaluation matrix: Assuming that there are m evaluated objects and an evaluation index for each evaluated object, the original matrix X of global equity level is.

$$X = \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix} \tag{1}$$

Data normalization: The original matrix X is normalized using the polar difference normalization method to obtain the standard matrix R.

$$R = \begin{pmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{pmatrix} \tag{2}$$

The following equations calculate the positive and negative indicators.

$$r_{ij}^{+} = \frac{x_{ij} - x_{imin}}{ximin_{imax}} \tag{3}$$

$$r_{ij}^{-} = \frac{xij_{imax}}{ximin_{imax}} \tag{4}$$

Where: x_{ij} is the initial value of the$i$indicator of the$j$evaluation object; r_{ij}^{+} and r_{ij}^{-} are the standardized values of the positive and negative indicators, respectively; $i = 1,2,\dots,m,m$ is the number of evaluation indicators; $j = 1,2,\dots,n,n$ is the number of evaluation objects; x_{imin} and x_{imax} are the minimum and maximum values of the first indicator, respectively.

Determination of index weight: the entropy weight method is used to determine the weight of each index ω_i. The calculation formula of entropy weight is:

$$\omega_i = \frac{1-H_i}{\sum_{i=1}^{m}(1-H_i)} \tag{5}$$

Where: $H_i = -\frac{1}{ln\, n}\sum_{j=1}^{n} p_{ij}\, ln\, p_{ij}$ is called information entropy, $p_{ij} = \frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}}$ is called the characteristic proportion of the indicator, $\omega_i \in [0,1]$ and $\sum_{i=1}^{m} \omega_i = 1$.

Establish weighted decision matrix: the weighted decision matrix Y is obtained by combining the standard matrix R with the weight of each index ω_i.

$$Y = \begin{pmatrix} y_{11} & \cdots & y_{1n} \\ \vdots & \ddots & \vdots \\ y_{m1} & \cdots & y_{mn} \end{pmatrix} = \begin{pmatrix} y_{11} \cdot \omega_1 & \cdots & y_{1n} \cdot \omega_1 \\ \vdots & \ddots & \vdots \\ y_{m1} \cdot \omega_m & \cdots & y_{mn} \cdot \omega_m \end{pmatrix} \tag{6}$$

Determine the positive ideal solution S_j^{+} and negative ideal solution S_j^{-}: Set S_j^{+} as the maximum value of the i index in the evaluation data in j year, that is, the positive ideal solution; Similarly, S_j^{-} is a negative ideal solution, and its calculation method is shown in Eq.7 and Eq.8.

$$S_j^{+} = max(r_{1j}, r_{2j}, \cdots, r_{nj}) \tag{7}$$

$$S_j^{-} = min(r_{1j}, r_{2j}, \cdots, r_{nj}) \tag{8}$$

Calculate the Euclidean Distance between each scheme and positive ideal solution and negative ideal solution:

$$sep_i^+ = \sqrt{\sum_{j=1}^{n}(S_j^+ - r_{ij})^2} \tag{9}$$

$$sep_i^- = \sqrt{\sum_{j=1}^{n}(S_j^- - r_{ij})^2} \tag{10}$$

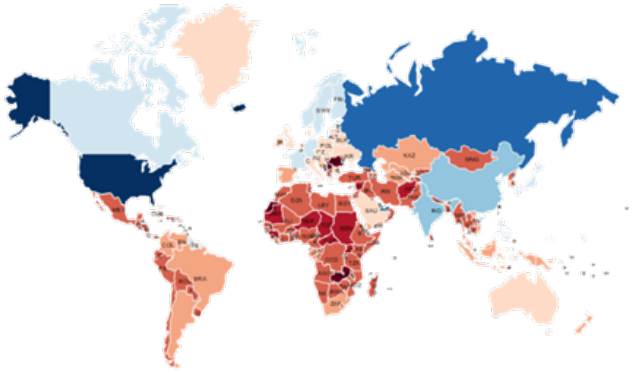
Calculate the comprehensive evaluation index:

$$C_i = \frac{sep_i^-}{sep_i^+ + sep_i^-} \tag{11}$$

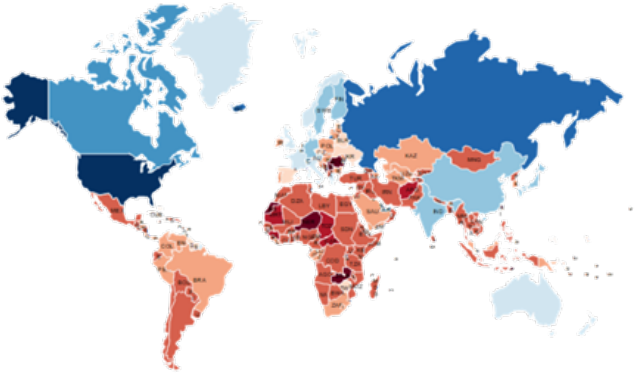
Where: $C_i \in [0,1]$, the greater the C_i, it means that the evaluation object is getting better.

3. Model Solving

First, use Eq.3 and Eq.4 to standardize the original data, and then use Eq.5 to determine the weights of the above indicators according to the entropy method, thereby obtaining the weights of each index. Combining with the results and the standardized matrix, 233 countries is calculated the weighted target decision matrix and determined the positive and negative ideal solutions. Regions around the world according to Eq.7 and Eq.8, then use Eq.9, Eq.10, and Eq.11 to combine with the weighted decision matrix to find out 1979-2019 years close to or deviate from the positive, the Euclidean distance of the negative ideal solution, and the sticking progress with the positive and negative ideal solutions, and dynamically sorted according to the ranking changes from 1979 to 2019. We visualize these scores as follows:



1979



1989

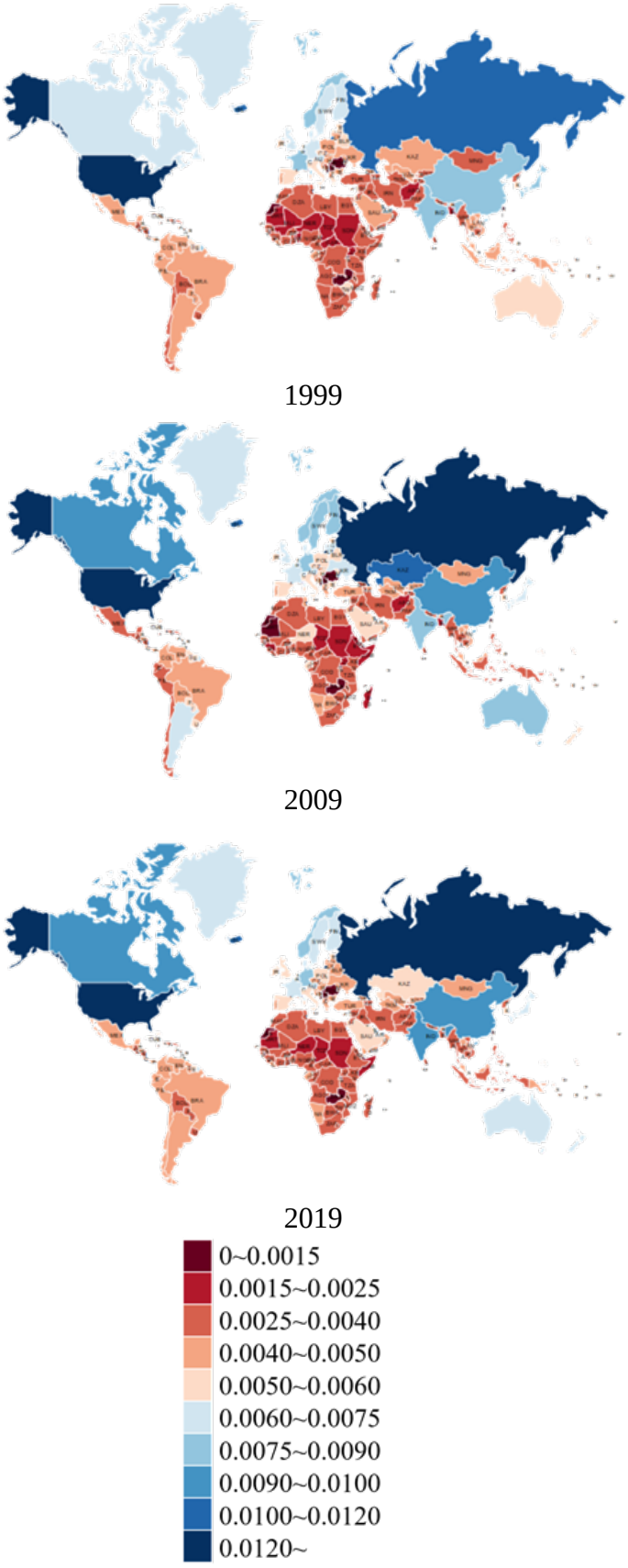


Figure 1. Distribution of Ci Score

The five maps above reflect the C_i scores of countries, reflecting the geographical and historical distribution of resources (including material and intangible) enjoyed by countries, and inequity exists worldwide. Although the scores of countries vary relatively, the distribution of resources tends to be

concentrated in parts of Europe, the Americas, and Asia, and these tendencies have not changed significantly over time.

The previous section calculates relative scores, representing each country's resource enjoyment using the entropy-weighted TOPSIS model, which summed to 1. Ideally, the scores of each country should be the same. In other words, as countries accumulate, the total score should increase proportionally, which can be represented by line L in Figure 2. However, the reality may be closer to the curve M (the scores are sorted from small to large and accumulated). A small number of countries enjoy more resources, while most countries have relatively few resources, which will lead to inequity on a global scale. The larger the shaded area A, the more serious the inequity is. We will quantify this level of inequity by referring to how the Gini coefficient is calculated to derive a global equity index.

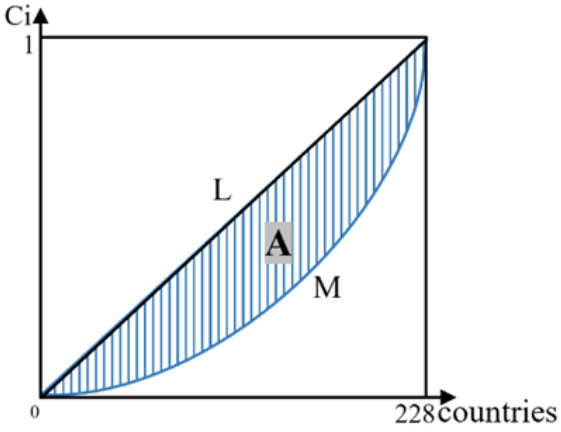


Figure 2. Reference for the Distribution of Country Scores Ci

The Gini coefficient is an indicator used to judge whether the income distribution is fair or not based on the Lorenz curve. It is a proportional value between 0 and 1, with closer to 0 indicating an equal distribution of income and 1 indicating unequal income distribution. [10]

The formula for calculating the Gini coefficient K is as follows:

$$K = \sum_{i=1}^{m} N_i T_i + 2\sum_{i=1}^{m} N_i(1 - V_i) - 1 \tag{12}$$

N represents the population proportion of each income group, T represents each group's income proportion, V represents each group's cumulative income proportion, and m represents the number of groups.

According to the scoring results of the TOPSIS model, it can be seen that:

$$\sum_{i=1}^{n} C_i = 1 \tag{13}$$

Since one score corresponds to one country, it is reflected in the formula of the Gini coefficient as Ni ≡ n (n represents the number of countries), from which we can obtain the calculation formula of the global equity index:

$$G = \frac{1}{n}\sum_{i=1}^{n} C_i + \frac{2}{n}\sum_{i=1}^{n} (1 - P_i) - 1 \tag{14}$$

Where C_i is the score of each country, P is the cumulative score, and n is the number of countries? After we sort the research objects according to the score C_1 of each country and region from low to high, we can calculate the global equity index G according to Eq.14.

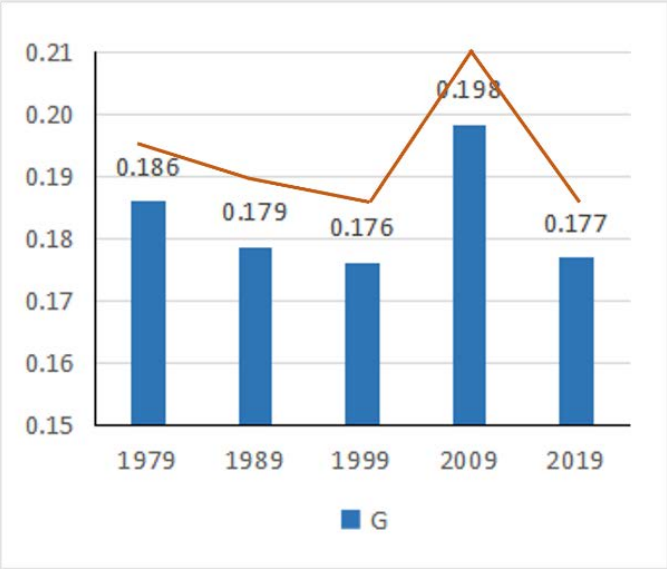


Figure 3. Global Equity Index

Like the Gini coefficient, the closer the global equity index is to 0, the more equitable the distribution of scores among countries, that is, the more equitable the resources people in all countries in the world enjoy, and vice versa. Excluding the abnormal year 2009, the global equity index showed a downward trend in the selected years. There was a certain degree of equity improvement globally.

4. Conclusion

In this paper, we set a reasonable definition for global equity and select some indicators that can measure the level of global equity from five dimensions: economic, technological, energy, political, and ecological, and construct an entropy-weighted TOPSIS model. The model is used to synthesize the scores of each indicator of each country and region in different historical periods. The global equity coefficient is derived by referring to and improving the calculation method of the Gini coefficient to quantify this inequity level.

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