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Evaluation of Space Mining from the Perspective of Global Equity

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Abstract

With the gradual maturity of space and space technology in the future, mankind will usher in the status quo of large-scale exploitation of space resources in the near future. However, due to the uncertainty of the future situation and the limitations of development conditions, space mining will have a far-reaching impact on the world. This paper determines the relevant 12 sub indicators, adopts TOPSIS method and unfair variation index (CV), establishes a measurement model of global equity, and selects 21 countries according to intercontinental geography and national development level to verify the regional equality. The paper proposes to establish a win-win cooperation mechanism and strengthen resource exchange and other relevant policy suggestions to safeguard the common interests of mankind.

Keywords

Global Equity; Space Mining; TOPSIS; Coefficient of Variation.

1. Introduction

In 1980, Dennis Hope, an American man, took advantage of the legal loopholes in the outer space treaty to openly sell the lunar land for personal interests, and then the planetary resources company and the deep space industry company attempted to mine small planets, and various private enterprises and academic institutions rushed into space to seize the "money tree" of space. The difficult problem of how to divide the rights and allocate resources is gradually developing from interest conflict to political struggle. There are various signs that the concept of "promoting the sharing of space resources by all countries" emphasized in the outer space treaty has not been perfected and effectively implemented [1].

It is undeniable that this fair international commitment has always been an important cornerstone of outer space governance, and the current series of "outer space constitutions" have been promulgated on the basis of the principle of sustainable development and benefit sharing. These legal provisions strive to find a balance between national interest fairness and political feasibility, to some extent, it also represents the understanding of some developed countries and emerging economies on the meaning of "equity" in the future exploration and utilization of international outer space resources.

Due to the differences in the global regional geographical environment, as well as the different cultural and historical backgrounds, various countries are faced with the status quo of extreme uneven development. There are significant differences in science and technology, education, energy and economic development. Therefore, from the perspective of regional differences, this paper will build a global equity model by integrating the degree of interaction between the economic level, the natural level, the energy level, the higher education level and the technical level, so as to further put forward the optimal solution to the allocation of outer space resources, analyze the factors and reasons affecting global equity, and put forward reasonable policy recommendations to better adapt to the political and commercial situation [2].

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2. Research Methods

2.1. Selection of Indicators and Research Objects

As space resource allocation involves different subsystems and multi-dimensional coordination at different levels of the composite system of energy technology, ecological environment and social economy, the efficiency index, on the one hand, should analyze the factors affecting the input and output benefits of space resources, on the other hand, should fully consider regional development and environmental differences. This paper selects 12 indicators from the four levels of economy, energy, education and technology, selects and collects relevant data from 21 representative countries such as Canada, the United States, China and the United Kingdom from developed and developing countries for empirical analysis, so as to evaluate the "worth" strength of countries in obtaining resources.

Science and technology, education, energy and economy have the most significant impact on "equity". Among them, the energy level indicators include national carbon dioxide emissions, energy consumption and production of major energy products; The economic level includes three indicators: total trade import and export, GDP and industrial output value; The educational level includes educational investment, enrollment rate of higher education and the amount of academic literature published; The scientific and technological level includes three indicators: the number of resident patents, the number of non resident patents and the investment in scientific and technological innovation [3].

In order to reasonably evaluate global equity, this paper uses the comprehensive ability of efficiency indicators to measure the degree of national equity. The higher the comprehensive score is, the greater the potential of the country in economy, energy, higher education and technology, the stronger the comprehensive strength, and the more opportunities to obtain more resources. By studying the differences among countries to reflect the global regional strength gap, we can measure the global equity (based on the recognition of the phenomenon of "those who can get it"). The greater the comprehensive score gap, the greater the monthly disparity in the ability to obtain resources. The more significant the inequality is, the more unfair the world is.

Considering the differences brought about by the global geographical environment, this paper takes intercontinental regions as the research samples, and takes some countries from six continents as the research samples. According to the development level of countries within each continent, some developed countries and developing countries are selected as the research objects. See Figure 1 for specific countries.

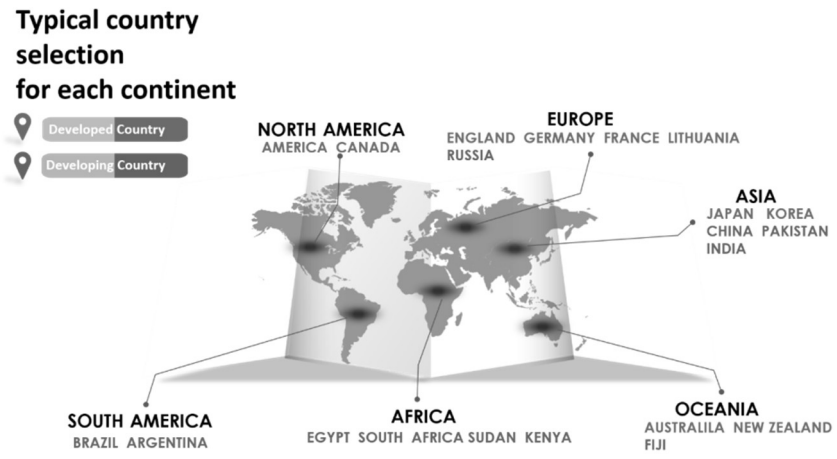

Figure 1. Typical country selection for each continent

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2.2. Definition of Equity Indicators

After calculating the optimal relative score of each country, we introduce the coefficient of variation to quantitatively measure the gap between different countries. The coefficient of variation reflects the absolute value of the degree of dispersion between data, which can explain the difference in access to resources and opportunities between different countries to a certain extent. We believe that the greater the coefficient of variation, the greater the degree of differences among countries, and the more uneven the distribution of resources, that is, unfair. Otherwise, it means relatively fair [4]. The specific calculation formula is as follows.

$$C \cdot V = \frac{\overline{S_i}}{\sqrt{\frac{1}{n}\sum_i^n S_i}} \tag{1}$$

Where, $\overline{S_i}$ represents the mean value of data, $\frac{1}{n}\sum_i^n S_i$ represents the standard deviation of data. For convenience of understanding, we define the actual meaning represented by the coefficient of variation as "fair index".

3. Model Construction

In this paper, TOPSIS method is used to solve the comprehensive score of resource allocation efficiency capacity of various countries. Through certain calculation, the closeness between each scheme and the optimal scheme is obtained, which is used as the evaluation standard for the advantages and disadvantages of each scheme. Finally, the advantages and disadvantages of each scheme are obtained. If a country is closer to the ideal optimal solution, we have reason to think that it is better. On the contrary, it is not good.

The distance scoring method of TOPSIS is as follows:

$$\frac{z_i - z_{min}}{z_{max} - z_{min}} \tag{2}$$

Where, z_i is the vector composed of the data values of each indicator in the ith scheme, z_{min} is the vector composed of the value of the worst solution of all indicators, z_{max} is the vector formed by the value of the optimal solution in all indicators. In order to emphasize the concept of comprehensive distance, the following formula is used for deformation:

$$\frac{z_i - z_{min}}{(z_{max} - z_i) + (z_i - z_{min})} \tag{3}$$

3.1. Data Forward Processing

Some of the indicators selected in this paper are very large data (the larger the better) and some are very small data (the smaller the better). Therefore, the following changes need to be adopted to convert them all into very large data. Where x_i is the specific value corresponding to this indicator.

$$\widehat{x_i} = max - x_i \tag{4}$$

3.2. Data Standardization Processing

Assuming that there are n schemes to be evaluated and m indicators, in order to eliminate the impact of different data indicators, we continue to standardize the positive data to obtain a standardized matrix reflecting the comprehensive strength of the national economy, science

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and technology, energy and education [5]. The matrix is standardized according to the following calculation formula.

$$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \tag{5}$$

Where, $z_i$represents the ith scheme, $z_i = [z_{i1}, z_{i2}, \cdots\cdots, z_{im}]$.
After the forward processing and standardization processing, the scoring matrix Z is obtained. Taking the number of countries studied as the number of rows and the number of indicators as the number of columns, the comprehensive strength evaluation matrix of national economy, science and technology, energy and education is constructed:

$$z = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1m} \\ z_{21} & z_{22} & \cdots & z_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ z_{n1} & z_{n2} & \cdots & z_{nn} \end{bmatrix} \tag{6}$$

Accordingly, we select the largest number in each column to form the ideal optimal solution vector.

$$z^+ = [z_1^+, z_2^+, \cdots, z_m^+] = [max\{z_{11}, z_{21}, \cdots, z_{n1}\}, max\{z_{12}, z_{22}, \cdots, z_{n2}\}, max\{z_{1m}, z_{2m}, \cdots, z_{nm}\}] \tag{7}$$

Similarly, take the smallest value of each column to calculate the ideal worst solution vector. Where,z^+represents,z^-representsz_{min}, calculate the score of each country according to the formula and sort it [6].

$$\frac{z_i - z_{min}}{(z_{max} - z_i) + (z_i - z_{min})} \tag{8}$$

For the ith scheme z_i. We calculate its distance from the optimal solution:

$$d_i^+ = \sqrt{\sum_{j=1}^{m} (z_j^+ - z_{ij})^2} \tag{9}$$

Calculate its distance from the worst solution:

$$d_i^- = \sqrt{\sum_{j=1}^{m} (z_j^- - z_{ij})^2} \tag{10}$$

Define the score of the ith country as:

$$s_i = \frac{d^-}{d_i^+ + d_i^-} \tag{11}$$

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4. Result Analysis

According to the above calculation steps, we calculate the data of 12 indicators of 21 countries, and then get the specific scoring indicators of different countries, and get the specific scores of each country on the efficiency of economy, science and technology, energy and education. Based on the scores, we rank the comprehensive efficiency capacity of many countries as follows, and further calculate the coefficient of variation as 0.6148. The regional distribution of comprehensive scores of each country is uneven, and the scores are different, According to the coefficient of variation of 0.6148 > 0.5, the fact that the world is "unfair" is further verified.

In addition, the mapping trend of XZ and YZ data on the one hand reflects the change trend of the comprehensive efficiency of each country from south to North and from west to East, that is, the comprehensive scores of each country from south to North show a general outline of high in the middle and low on both sides, while from east to west, the comprehensive scores of each country show a bimodal shape.

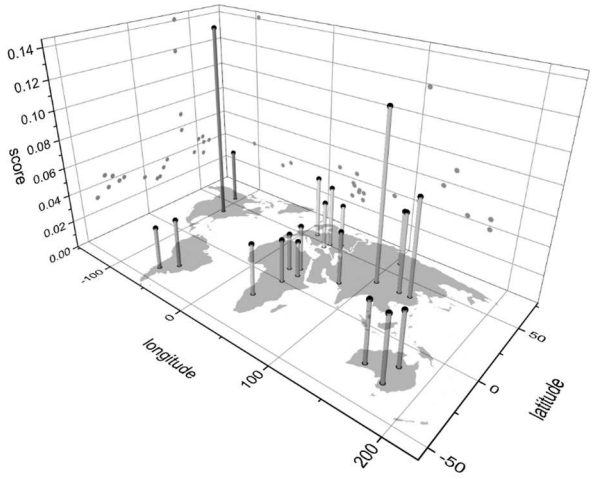

Figure 2. Global Equity Score on Spatial Distribution

From the figure, Europe and North America have the potential to obtain more resources than other states. The data shows that the comprehensive score of the United States is 0.1409, ranking first among the 21 research countries. This also shows that the United States has a strong advantage in international competition and is one of the strong competitors in the world. At the same time, countries in South America, North America and Asia are faced with relatively serious inequality differences, and the gap with the global average is 1.6392, 0.7863 and 0.5828 respectively. In terms of data, North America has the largest equity index and the most "equity", followed by South America, Asia, Europe, Africa and Antarctica.

5. Suggestions

In view of the "battle for space resources" among countries and even enterprises caused by asteroid mining, it is necessary for all countries to update and supplement more detailed laws and frameworks to strictly regulate their activities in outer space on the basis of the outer space treaty and in combination with the uniqueness of the development of outer space mineral resources, so that the Treaty can better adapt to the contemporary international political situation and industrial development situation. This paper puts forward the following policy recommendations:

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(1) Establish an incentive mechanism. The United Nations should encourage all countries to actively explore space resources and provide incentives to countries or private enterprises that dare to explore space through the establishment of certain international incentive mechanisms.

(2) Allow public resource exchanges. The United Nations should stipulate in writing the contents that can be exchanged, such as a certain technology, some mineral resources, etc., and the United Nations will conduct secondary distribution of these benefit exchange products (mainly to compensate regions with low fairness in the world). This paradigm shift based on the secondary distribution of the United Nations (this word is not right) is of great value in the construction and improvement of the global equity model [7].

(3) Establish a sharing mechanism. The United Nations should design a reasonable sharing mechanism to achieve the balance of international political interests. For example, it should stipulate that countries exploiting outer space resources should give priority to transferring resources to the countries of astronauts engaged in deep space exploration, or force them to share 80% of the mineral resources in the legend of space mining, so as to keep the research gap of global space resources within a certain range.

(4) Set up a cooperation mechanism The United Nations can actively encourage the development and exploitation of outer space resources through certain forms of international cooperation. For countries that cooperate in mining, the United Nations should draft international agreements (contracts).

To sum up, cooperation mechanism, incentive mechanism and sharing mechanism work together to jointly balance various interests, divide rights and obligations, and divide risks and responsibilities, which is the best way to avoid vicious competition in space mining, and to abide by and realize the principle of "working for the welfare of all mankind".

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