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Research on Asteroid Mining Based on Entropy Weight Fair Index Evaluation System

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Abstract: *The universe is rich in mineral resources. With the rapid development of commercial space flight, people gradually begin to consider the possibility of asteroid mining. In this paper, we have developed a set of measurement models to assess the level of capacity of countries. In this paper, we first select the original data of 13 indicators from 106 countries and use entropy method to determine the weight of these 13 indicators. On this basis, a global equity index evaluation system model based on TOPSIS is established to score the fairness of these countries. In view of the future development of asteroid mining industry, we analyze the possibility of asteroid mining in the future from three aspects: capital, technical capacity and mineral trade.*

Keywords: *Small planet mining; TOPSIS; Index system; Entropy weighting method*

1. Introduction

With the rapid development of aerospace science and technology, more and more countries are turning their attention to the vast space for mineral development. Space is rich in mineral resources. For example, the asteroid 16Psyche has a small amount of iron resources, and the Gaspra and Ida asteroids are rich in metals [1].

In planning the mining of asteroid resources, we need to consider the feasibility, development costs, economic benefits, and the attribution of interests in mining, transportation, and other technical aspects. More importantly, it is necessary to consider how we should maintain or even improve global equity in such an era of space resource utilization. So that we can use space resources to benefit mankind more effectively in the future

2. Global Equity measurement method

2.1. The Definition of Global Equity

The following definition of global equity: Global equity refers to the norm or principle for the rational allocation of economic, natural, and other resources based on the political, economic, educational, cultural, environmental, and other development levels of each country or region in the world [2-4].

2.2. Indicator Selection

According to the definition of global equity, to comprehensively assess global equity, the indicators to be selected should be able to show the resolution of common contradictions in the development of human society and the differences between countries. These common problems are mainly reflected in politics, economy, education, culture, and environment, including economic level, population level, social security, population health, education popularization, resource availability, gender equality, and so on. To quantitatively describe the above, we have selected the following 13 indicators [5].

This paper select the 13 indicators describing global equity above to assess the global equity index of 106 countries in the world. By collecting the index data of 106 countries, TOPSIS ideal solution method is used to solve the calculation.

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Table 1: Indicators and Explanation

Indicators	Explanation
Poverty	The proportion of population living with less than 1.90$ per day.
Gini index	The Gini index is a measure of the distribution of income across a population.
FDI	Foreign direct investment (FDI) are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments.
Unemployment rate	Unemployment refers to the share of the labor force that is without work but available for and seeking employment.
UHC	The Universal Health Coverage (UHC) Index is measured on a scale from 0 (worst) to 100 (best) based on the average coverage of essential services including reproductive, maternal, newborn and child health, infectious diseases, non-communicable diseases and service capacity and access.
Improved water source	the population without access to an improved water source
Clean fuels	Access to clean fuels or technologies such as clean cookstoves reduce exposure to indoor air pollutants, a leading cause of death in low-income households.
Compulsory education	The number of years that children are legally obliged to attend school.
Proportion of female	The proportion of female in the population
F-M labor force participation	This ratio is calculated by dividing the labor force participation rate among women, by the corresponding rate for men. The labor force participation rate is the proportion of the population aged 15 years and older that is economically active.
Customs tariff	Weighted mean applied tariff is the average of effectively applied rates weighted by the product import shares corresponding to each partner country.
Annual CO_2 emissions	Carbon dioxide (CO_2) emissions from the burning of fossil fuels for energy and cement production.
Population	Total population.

3. Model preparation and data preprocessing

3.1. Data Preprocessing

In the environmental quality index, there are multiple indicators, including three benefit indicators and one cost indicator. The larger the value of the indicator, the better the quality is. The dimensions of these indicators are different, so data pre-processing, dimensionless and normalization are required before processing. In this paper, standard 0-1 transformation is used for these benefit indicators, so that the optimal value of each indicator attribute is 1 and the worst value is 0.

3.2. Assumptions

Statistics we collect from the website are actual and reliable. The global economic, political, cultural, and environmental conditions are relatively stable. Global equity is only related to our evaluation indicators. And the asteroid mining industry can develop according to the vision we proposed, the asteroid mining industry has an impact on global equity, and only on the indicators we specify.

4. TOPSIS Model Based on Entropy Weight Method

4.1. Model building

Firstly, construct the weighted gauge matrix. The weight vector is obtained by entropy weight method and the weighted gauge matrix is constructed.

Secondly, determine the positive ideal solution C* and the negative ideal solution C^0. Let the jth attribute value of positive ideal solution C* be C_j^* and the Jth attribute value of negative ideal solution C^0 be C_j^0, then:

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$$\text{the positive ideal solution } c_j^* = \begin{cases} maxc_{ij}, \text{j is the benefit attribute} \\ minc_{ij}, \text{j is the cost attribute} \end{cases} \quad j = 1,2,\dots,m; \tag{1}$$

$$\text{the negative ideal solution} c_j^0 = \begin{cases} minc_{ij}, \text{j is the benefit attribute} \\ maxc_{ij}, \text{j is the cost attribute} \end{cases} \quad j = 1,2,\dots,n. \tag{2}$$

Then, calculate the distance between each scheme and the positive ideal solution or the negative ideal solution. The distance between alternative di and the positive ideal solution is:

$$s_i^* = \sqrt{\sum_{j=1}^{n}(c_{ij} - c_j^*)^2} \quad ,i = 1,2,\dots,m \tag{3}$$

The distance between alternative d_i and the negative ideal solution is:

$$s_i^0 = \sqrt{\sum_{j=1}^{n}(c_{ij} - c_j^0)^2} \quad ,i = 1,2,\dots,m \tag{4}$$

The ranking index value of each scheme is calculated to obtain the comprehensive evaluation index, and the calculation formula is:

$$f_i^* = \frac{s_i^0}{s_i^0 + s_i^*}, \quad i = 1,2,\dots,m \tag{5}$$

The f_i^* obtained is the evaluation score.

4.2. Analysis and Evaluation of results

According to the data found on the "Our World in Data" website (https://ourworldindata.org), we used the entropy weight method to determine the weights of 13 indicators. The results are as follows.

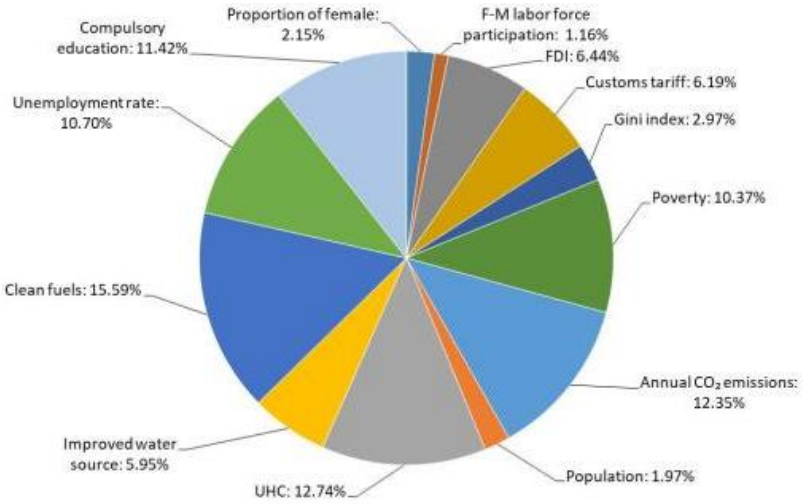

Figure 1: The Weight of 13 Indicators

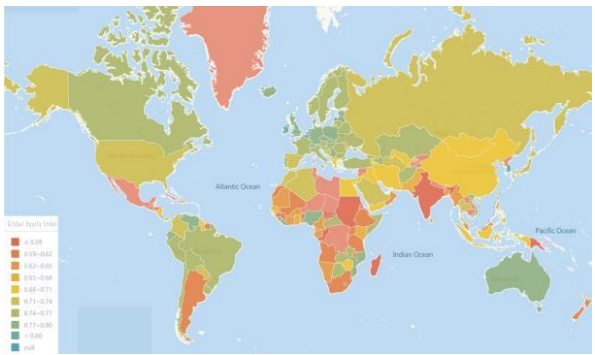

Figure 2: The Color-block World Map of Global Equity Index

To get an overview of the world's global equity situation, we create a color-block world map to show the global equity index in each country. Color block world map above. As can be seen from the figure,

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the global equity index of developed countries in Europe and the United States is relatively high [6], while that of Africa, where backward countries gather, is generally backward. This difference is mostly due to the degree of development, with more developed regions attaching greater importance to the concept of equity and being more able to achieve it.

In our view, the world now is open and inclusive. To safeguard global equity, we should not only maintain the relationship of equality and reciprocity between countries, but also make efforts to improve the living standards of Chinese people, guarantee the right of citizens to receive education, and maintain equal relations between citizens of different genders.

5. The Future and Impact of Asteroid Mining

5.1. Model Establishment

This paper proposes a possible and reasonable vision for the future of asteroid mining from the following three perspectives.

(a) Capital: Capital determines who is responsible for asteroid mining and where it is financed. Based on the current level of development, asteroid mining will be a cost-intensive industry for a long time to come, so individuals and small businesses cannot afford it. Funding for the future asteroid mining industry will be the responsibility of four types of organizations: national governments, large corporations, scientific research institutes, and international organizations.

(b) Technical Capability: We propose a way: developed countries that master technology provide talent and technology, while developing countries and large population countries manufacture mining machines and provide labor for asteroid mining.

(c) Mineral Trade: We propose a trade method: the international organization of asteroid mining will uniformly evaluate and determine the price of the minerals owned by each asteroid, and each country or organization has an equal opportunity to purchase the mined minerals. Asteroid mining is an excellent way to provide relatively low-priced mineral resources for these countries. If the asteroid mining market is monopolized, it will be more difficult for these countries to progress. It will cause social instability and violates the purpose of global equity. Therefore, this unified price, open-purchase trade method is justified.

5.2. The Impact of Asteroid Mining on Global Equity

According to the proposed vision and previous evaluation results, we added and deleted the evaluation indicators according to the importance of the 13 indicators and the possible impact of the new industry [7-8]. Three indicators with a weight of less than 2.5% were deleted, namely the Proportion of women, the F-M labor force participation, and the Population. Two indicators, academic journals, and natural resources rents have been added, which can largely reflect the impact of technological capability and mineral trade on global equity. Then we re-measure using the global equity model. The table below is an explanation of the new indicators.

Table 2: New Indicators and Explanation

Indicators	Explanation
Journal articles	Scientific and technical journal articles refer to the number of scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering, and technology, and earth and space sciences. Location is allocated by the country of institution.
Nature resources rents	Natural resources rents are estimated as the difference between the price of a commodity and the average cost of producing it. Total natural resources rents are the sum of oil rents, natural gas rents, coal rents, mineral rents, and forest rents.

5.3. Model Solving

We recalculate the weights after changing the indicators.

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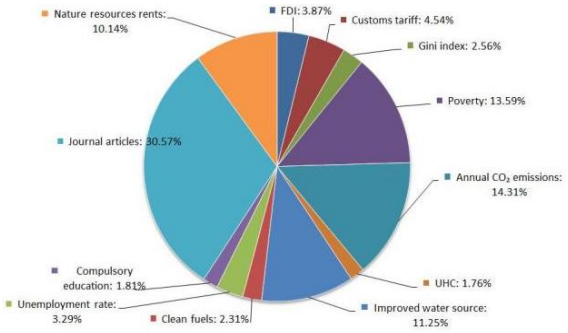

Figure 3: Index Weight Distribution Under Influence

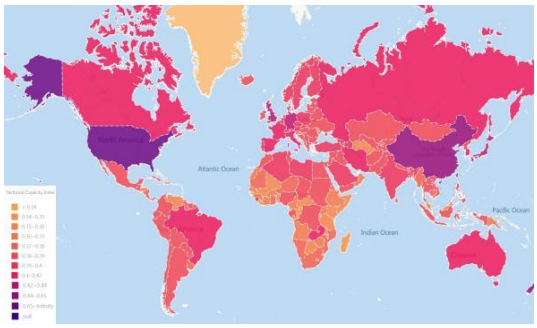

Figure 4: Color Block World Map of Mining Asteroid Mining Effects

It can be seen from the figure 4 that the vision proposed by us has a negative impact on global equity, which is mainly reflected in the significant decline of the global equity index of countries with relatively backward technological capabilities, while the global equity index of developed countries is still at a high level. This is because backward countries can only benefit from the asteroid mining industry by providing labor, which puts them at a disadvantage.

6. Conclusion

Around asteroid mining, this paper develops a set of measurement models to assess the level of capacity of countries. This paper first selects the original data of 13 indicators from 106 countries, including the employment rate of men and women, annual carbon dioxide emissions, the proportion of people using clean energy and unemployment. Then we establish the definition of global equity, use entropy method to determine the weight of these 13 indicators, and establish a global equity index evaluation system model based on the principle of TOPSIS ideal solution. In view of the future development of asteroid mining industry, we analyze the possibility of asteroid mining in the future from three aspects: capital, technical capacity and mineral trade. According to the scoring results, the early plans of the asteroid mining industry in the United States, China, Britain, Germany, Japan and other major countries are determined. Through comparison and verification with the latest literature, we have learned about the development plans and official policies of these countries related to the asteroid mining industry, and assessed the reasonableness of our forecasts for the future of asteroid mining.

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