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Asteroid Mining Boom, Where Will Global Equity Go?

Ruilin Ye[1,*], Haoyi He[2], Yiqi Duan[2], Jiahe Liu[1]

[1]*School of Economics, Northeastern University at Qinhuangdao, Qinhuangdao, Hebei, 066004, China*

[2]*School of Computer and Communication Engineering, Northeastern University at Qinhuangdao, Qinhuangdao, Hebei, 066004, China*

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Abstract: This paper builds a mathematical model based on differential equations, TOPSIS and other methods around the definition of global fairness and how it is affected by the asteroid mining industry. Specifically, we use the TOPSIS evaluation model based on the entropy weight method to score and rank the selected 36 representative countries to obtain the number of resources they deserve. By establishing differential equations for simulation, we concluded that 93% of asteroid ore will be occupied by the first type of countries. At the same time, we introduced the index of space science and technology. After using the AHP to determine its weight, we re-calculated the relative fairness coefficient of 0.17242 by systematic clustering, indicating that the global relative fairness has dropped significantly. Finally, a sensitivity analysis was performed on the considered models.

1. Introduction

Promoting global equity has always been the top priority of the United Nations. The outer space treaty proposed by it in 1967 was signed by most countries in the world. The treaty recognizes that when exploring and using outer space, regardless of the economic and technological level of the country, the space explored should be under the jurisdiction of all mankind. It also promotes global equity and reduces inequalities. But as the world's population continues to grow, mineral resources such as ferrous metal minerals (such as iron, manganese, chromium) and precious metal minerals (such as gold, silver, platinum) on the earth are very limited. And with the increasing mining intensity and demand, it is approaching depletion. People gradually set their sights on asteroids with abundant resources. On November 25, 2015, U.S. President Barack Obama signed the “Commercial space launch competitive-ness act”, It means that private companies have obtained legal rights on the basis that the exploitation of space resources and commercial use are technically possible. This ensures that the United States is at the forefront of space technology, inspiring the next generation of astronauts to explore outer space. In addition, most developed countries are constantly expanding the depth and breadth of space technology through space mining, which is bound to have an impact on global equity.

In this paper, we first select indicators such as economy, population, region, and development, collect and organize data on the World Bank [1] and other websites, establish a TOPSIS evaluation model based on the entropy weight method, and score and rank 36 representative countries around the world. Secondly, the future development pattern of asteroid mining under a kind of state monopoly cluster is simulated by using the differential equation model of population competition. At the same time, space technical indicators are introduced, and the weight of the indicators is determined by the analytic hierarchy process. In addition, we have changed the monopoly landscape of asteroid mining in the future. Four real-world similar scientific and technical indicators are introduced to calculate country scores, clustering to calculate centroid distances for each category, and changes in stake coefficients to determine when the visual selection conditions for future asteroid mining change [2]. Finally, we use differential equations to calculate the total global profitability index to ensure that asteroid mining is better for all mankind, and to propose reasonable and effective policies from the perspective of the United Nations.

2. Global Equity Measurer

Relative fairness is an understanding method based on the fairness coefficient (distance between cluster centers), which is proposed to better reflect the impact of asteroid mining on global fairness.

In order to quantify the resources that each country is worth, we firstly selected four major aspects such as economy, population, resources, and development, also there are 11 indicators such as GDP growth rate, total population, proportion of poor population, cereal output, per capita GDP, total amount of ores and metals, which is shown in Fig.1.

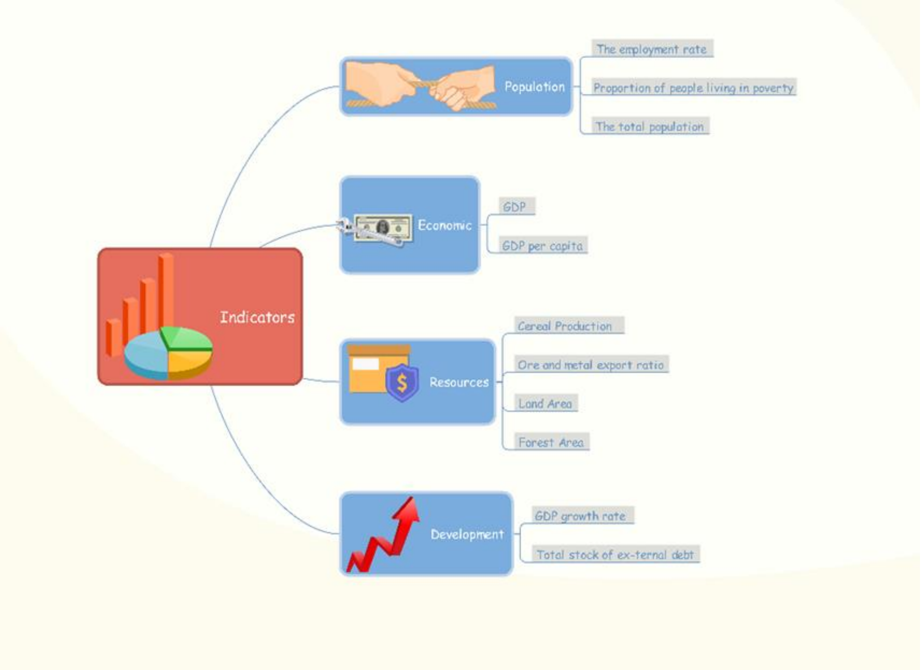

Figure 1 Select indicator graph

We use the entropy weight method to calculate the weight of each index in the following order. Judging whether the input matrices are all non-negative. Assuming there are n evaluation objects and m evaluation indicators, construct them into a positive matrix as follows:

$$X = \begin{vmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{vmatrix} \tag{1}$$

Denoting the standardized matrix as Z, and each element in Z indicate: $z_{ij} = x_{ij} / \sqrt{\sum_{i=1}^{n} x_{ij}^2}$.

Calculating the proportion of the i-th sample under the j-th index, and regard it as an overview of the relative entropy calculation. According to the calculation overview matrix P, the calculation formula for each element P_{ij} in P is:

$$p_{ij} = \frac{\tilde{z}_{ij}}{\sum_{i=1}^{n} \tilde{z}_{ij}} \tag{2}$$

Calculating the information entropy of each indicator, and normalize the entropy weight of each indicator. For the j-th indicator, the information entropy calculation formula is:

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \ (j = 1, 2, \cdots, m) \tag{3}$$

Defining maximum $Z^+ = (\max\{z_{11}, z_{21}, \cdots, z_{n1}\}, \max\{z_{12}, z_{22}, \cdots, z_{n2}\ \}, \max\{z_{1m}, z_{2m}, \cdots z_{nm}\})$ and minimum $Z^- = (\min\{z_{11}, z_{21}, \cdots, z_{n1}\}, \min\{z_{12}, z_{22}, \cdots, z_{n2}\ \}, \min\{z_{1m}, z_{2m}, \cdots z_{nm}\})$ Defining the distance between the i-th evaluation object and the maximum value $D_i^+ = \sqrt{\sum_{j=1}^{m} \omega_t (Z_j^+ - z_{ij})^2}$. From this, calculating the unnormalized score of the i-th evaluation index $S_i = \frac{D_i^-}{D_i^+ + D_i^-}$, and normalize the score to get $\widetilde{S}_i = S_i / \sum_{i=1}^{n} S_i$.

After collecting the data of various indicators of representative 36 countries, our team decided to use SPSS statistical software and the method of systematic clustering to divide the above countries into appropriate categories.

The distance between two different indicators adopts the absolute value distance and the Euclidean distance $d(\vec{x}_i, \vec{x}_j) = \sqrt{\sum_{k=1}^{p} (x_{ik} - x_{jk})^2}$. And multiple indicators can be grouped into classes by clustering, remember that G_p and G_q are two classes, and $D(G_p, G_q)$ is the distance between these two classes. $\vec{x}_i \in G_p$ $\vec{x}_j \in G_q$ $d(\vec{x}_i, \vec{x}_j)$ is the distance between the two samples. The distance between classes is taken Between-group Linkage $D(G_p, G_q) = \frac{d_1 + d_2 + d \cdots + d_n}{n}$.

In order to determine how the 36 representative countries should ultimately be grouped into categories, we decided to approximate the optimal number of clusters graphically based on the Elbow Rule. The sum of the distortion degrees of each class is the sum of the squares of the distances between the center of gravity of the class and the positions of its internal members. Supposing a total of n samples are divided into K categories, the results in shown in Fig.2.

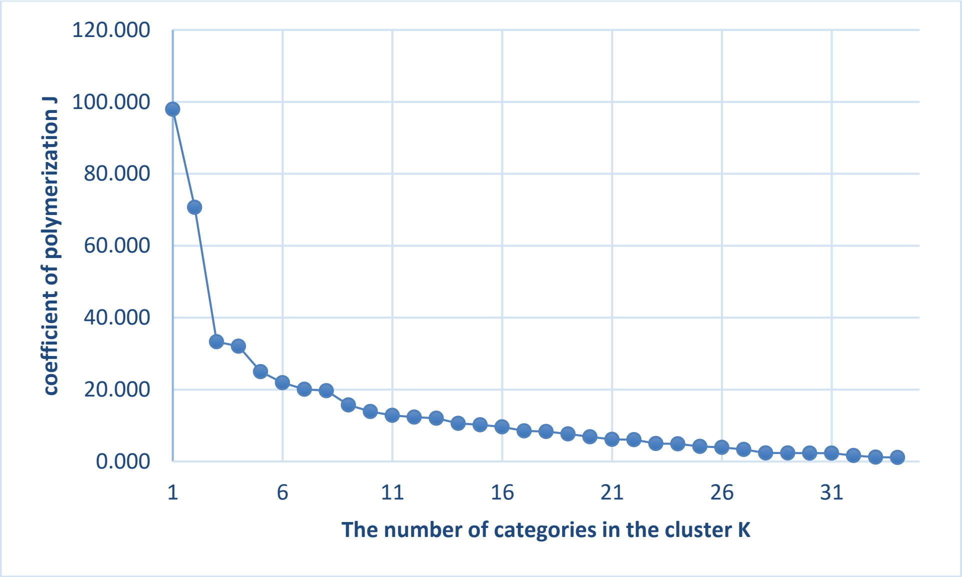

Figure 2 Aggregation coefficient line chart

As can be seen from Fig.2, when the number of categories K varies from 1 to 5, the change in the degree of distortion is the largest, and when K exceeds 5, the change in the degree of distortion decreases significantly. Thus, the k can be set to 5. However, considering the reality and genealogy map, we decided to revise the five categories determined by the elbow principle into three categories. The United States and China are the first category of high-contribution countries, and Russia, Japan, and India are the second category of medium-contribution countries. The rest of the countries, such as the UK and France, belong to the third category of low-contribution countries.

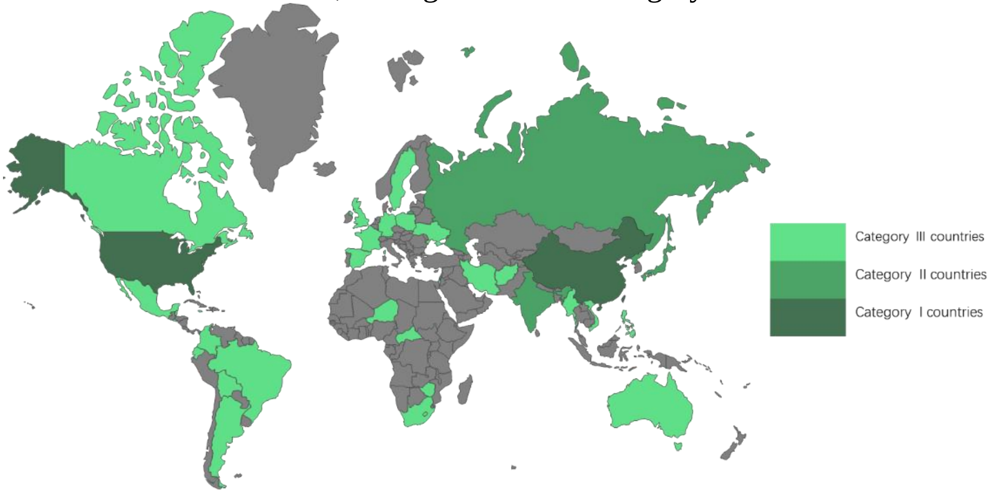

Figure 3 Distribution map of country classification results

Before being affected by asteroid mining, the fairness coefficient Γ of global relative fairness is 0.0568. The results of our team's classification of these 36 countries are shown in the Fig. 3 by the shade of color, and observe their regional distribution on a global scale: Africa and Oceania are mainly distributed in the third type of countries, Asia and the Americas are mainly distributed in the first and second types of countries, and Europe is mainly distributed in the second type of countries. This is also in line with the distribution of countries with comprehensive national strength in reality [3]. From a historical point of view, the global landscape changed after World War II. After World War II, the United States and the Soviet Union engaged in a Cold War and took all hostile actions except for direct military engagements. The Soviet Union eventually disintegrated, Russia fell into the second category of countries with many difficulties, and the United States became the only superpower [4]. In order to ease ethnic conflicts and prevent the recurrence of wars, Europe moved towards unity and developed steadily. After the reform and opening up, China's comprehensive national strength has been continuously enhanced, its international status has been continuously improved, and China has become an important force on the international political stage. This echoes the results of our comprehensive national strength evaluation model.

We set up the distribution performance scheme calculation model [1]:

$$S_n = \frac{100}{a_{\max}} \times a_n - K \times \sin\left(\frac{100}{a_{\max}} \times a_n \times \frac{2\pi}{a_{\max}}\right) \tag{4}$$

where $n=1,2,3\cdots,N$ is the country number, S_n is the standard score of the country's comprehensive national strength, a_n is the actual amount contributed by the country, $a_{\max}$ is the maximum value of the actual contribution of the country, $K=0\sim15$ is the management adjustment factor.

Taking K=15, the standard score of each country is calculated and normalized to calculate the proportion of resources that should be obtained. The result is shown in theFig.4.

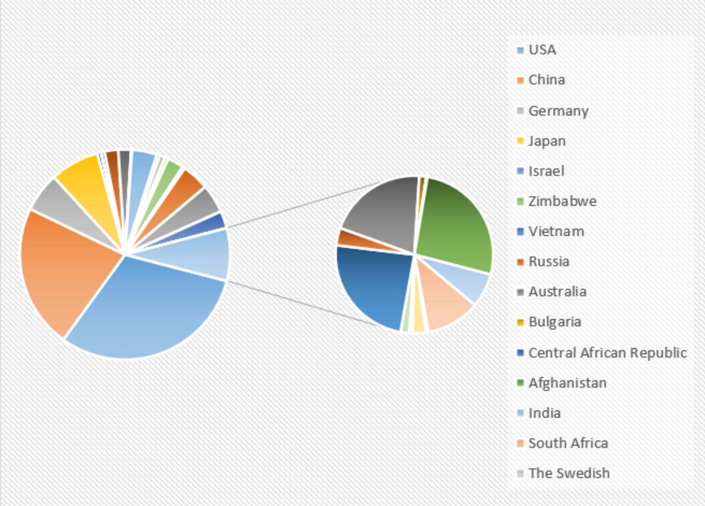

Figure 4 The proportion of resources that countries should allocate

From the perspective of absolute fairness defined by us, the proportion of resources on earth that should be allocated by the selected 36 representative countries is shown in the figure above. Under this distribution method, each country receives resources commensurate with its own capabilities and contributions.

3. Future Predictions: Asteroids with Big Impact

In such a non-perfectly competitive market, the remaining two categories of countries will be at a disadvantage and eventually withdraw from the market [5]. We apply a differential equation model to simulate the above-mentioned pattern of future mining of asteroids.

Considering the competitive effect of the three types of countries, the consumption of ore resources in any type of country will affect the growth of the other two types of countries, and the competition coefficient between different types of countries we study the relevant literature [3]. Finally, we use Matlab software for simulation, and the results are shown in Fig. 5.

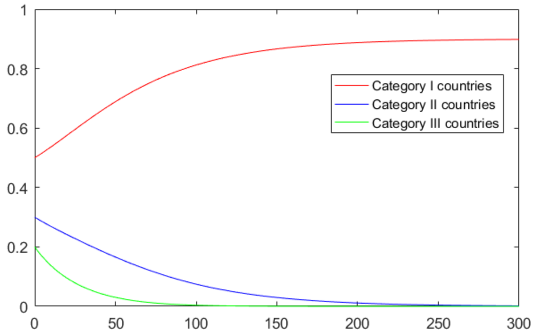

Figure 5 Asteroid mining monopoly in the future

As shown in Fig. 5, with the pass of time, the first type of country has continuously improved the depth and breadth of space technology, and finally occupies an absolute dominant position in the competition with the other two types of countries, and the allocation rate of asteroid ore resources is close to 93%, forming a monopoly situation. In this environment, the first group of countries will be mining, continuously capitalizing on technological dividends and earning huge profits from the sale of minerals.

The main impact of asteroid mining is technological factors. In order to explore how asteroid mining affects global fairness, we added the space technology ranking indicator to the evaluation model, its new weight distribution with other 11 indicators is obtained by AHP.

Finally, the weights of the 12 indicators are obtained as $\omega' = (0.015, 0.1465, 0.0235, 0.00605, 0.0105, 0.00475, 0.0679, 0.0725, 0.1434, 0.0048, 0.00405, 0.50105)$ We will add the possible scientific and technological data after the monopoly pattern is formed, and then re-score and rank in the evaluation model. And use the method of systematic clustering to calculate the coordinate value of the center point of the three types of countries and the fairness coefficient $\varGamma$, which is shown in table 1.

Table 1 Relatively equity center point coordinate values in case of monopoly

Clustering categories	Center point coordinate value ε'
Category 1 countries	0.10345
Category 2 countries	0.03793
Category 3 countries	0.01724

The fairness coefficient at this time $\varGamma'' = \sum_{i=1}^{3}\sum_{j=1}^{3} \varepsilon_i - \varepsilon_j = 0.17242$, It is obvious that the relative fairness coefficient has been greatly improved, indicating that after asteroid mining, the world has become relatively unfair.

4. Sensitivity Analysis

σ_2 is the ability of a developed country to provide scientific and technological assistance to developing countries. The more aid provided, the faster the development of the asteroid mining industry in developing countries, and the higher the profitability index, which will also promote the improvement of the profitability index of developed countries. In order to verify the sensitivity of the model, we set the fluctuation of σ_2 value at about 20%, select $\sigma_2' = 1.8$, $\sigma_2 = 2.0$, $\sigma_2'' = 2.2$ three values to draw the graph ,which is obtained in Fig. 6.

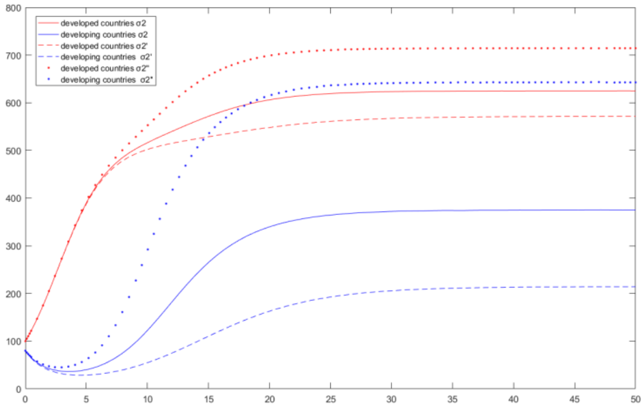

Figure 6 Sensitivity analysis plot of σ_2

It can be seen that the total profit coefficient of developed and developing countries is more sensitive to the change of σ_2. Under the upper and lower limits of the fluctuation range of σ, the global final profit coefficient M_2', M_2'' are 750 and 1370 respectively, with a range of 35.89% to 17.09%. This reflects the necessity of cooperation between developed and developing countries, and is in line with the purpose of this article. Countries around the world seek common ground while reserving differences, and help each other, so as to make the space mining cake bigger and benefit the development of all mankind.

5. Conclusion

In formulating the definition of global fairness, this paper starts from two perspectives, using a self-defined fairness coefficient to measure the relative fairness of the impact of asteroid mining, and using "distribution according to work" as a measure of absolute fairness. The TOPSIS evaluation model of the method was used to derive the model. To not only divide the asteroid mining pie, but expand it. We use differential equations to solve the global total profit index, thereby promoting the development of the interests of all mankind. Finally, under the leadership of the United Nations, developed countries provide scientific and technological assistance to developing countries, and developing countries relieve economic pressure on developed countries. When the two support each other, the global total profit index peaks at 1,170.

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