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A Measuring Stick for the World: Achieving Global Equity in Asteroid Mining

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Abstract: *In this paper, we analyze the impact of asteroid mining on global equity. Specifically, the analytic hierarchy process (AHP) and entropy weight method (EWM) are used to calculate the weight, and finally the weight factors are coupled. The TOPSIS model was used to establish a global fairness measurement model, and the model was used to calculate the per relatively equality allocation of weight (PREAW) for 40 countries. To address the question of how asteroid mining affects global equity, a grey prediction model was established. Through the processing of raw data, time series data is generated, and finally differential equations are established to predict future development trends. The asteroid mining factor is introduced into the global fairness measurement model to calculate PREAW, and it is found that the resource requirement (RR) has an important impact on global fairness.*

Keywords: *Global equity, asteroid mining, analytic hierarchy process (AHP), entropy weight method (EWM), grey prediction model*

1. Introduction

Resources are the important basis for human survival and production, and any social product is the result of resource conversion. With the development of society, the shortage of resources is becoming more and more serious, and human beings have become more and more enthusiastic about the exploration of space resources. Therefore, the exploration of space resources has become the commanding height of scientific and technological competition [1]. Under the appeal of the United Nations, most countries around the world signed the Outer Space Treaty, which has great significance for regulating the development of space resources.

According to their different orbits, the planets in the solar system can be subdivided into near-Earth asteroids and main belt asteroids, and relevant research results show that there are about 1500 near-Earth asteroids that can be used for human asteroid mining activities [2]. And with the increase of the number of space exploration and the improvement of space exploration capabilities, exploiting the rich resources of near-Earth asteroids may no longer be a fantasy. Compared with the current scarcity of resources on Earth, the wealth of asteroids would be attractive to any country [3].

In the future, if humanity has the ability to get asteroid minerals, how can we maintain the status quo of the global equality? Should a country which has stronger comprehensive national power and more advanced space exploration technology means occupying more space resources? The answer is, of course, no. We need to define the global equity, develop a scientifically accurate model to measure it, and come up with targets and possible measures for asteroid mining to truly benefit humanity.

2. Global Equity Measurement Model

In order to achieve the purpose of global equity, we considered from five dimensions, namely economic strength (ES), level of science and technology (LST), resource requirement (RR), international aid (IA) and intergenerational equity (IE). In order to comprehensively and objectively evaluate global equity, we calculate the weight of indicators from qualitative and quantitative aspects. Firstly, the AHP method was used to calculate the weight of 11 influencing factors in five directions, and then the EWM was used to avoid the subjectivity of AHP. Finally, the PREAW was obtained by coupling the weight factors.

2.1. Weight Calculation

Therefore, our indicators should also be divided into income indicators, cost indicators and deviation indicators. The normalization is as following:

The benefit-type index is:

$$y_i = \frac{x_i - \min\limits_{1<i<n}(x_i)}{\max\limits_{1<i<n}(x_i) - \min\limits_{1<i<n}(x_i)} \tag{1}$$

The cost-type index is:

$$y_i = \frac{\max\limits_{1<i<n}(x_i) - x_i}{\max\limits_{1<i<n}(x_i) - \min\limits_{1<i<n}(x_i)} \tag{2}$$

The deviation-type index is:

$$y_i = 1 - \frac{x_i - \beta}{\max\limits_{1<i<n}|x_i - \beta|} \tag{3}$$

According to the data characteristics, AHP was used to calculate the weight of the indexes, de-composed the complex system, and solved the decision problem by qualitative analysis of each index, which is shown in Fig.1.

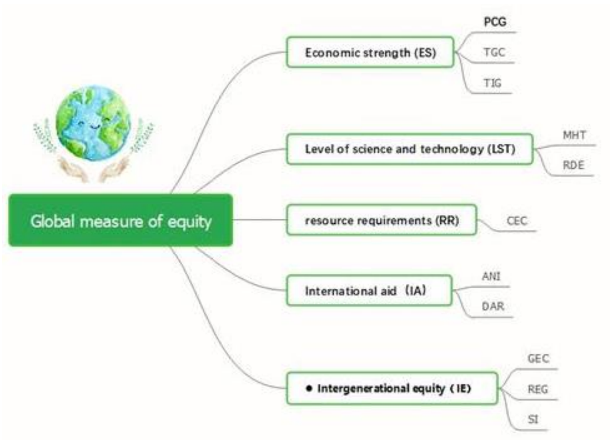

Figure 1: Global equity evaluation indicators

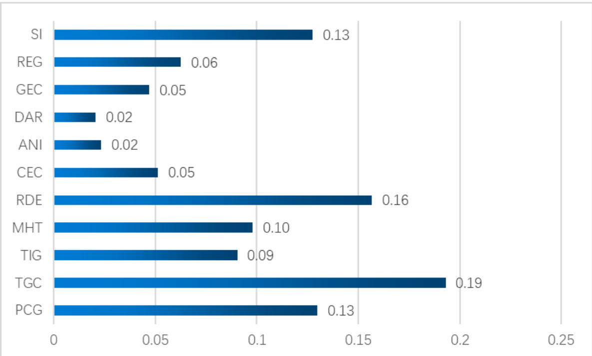

Figure 2: The weight of AHP

The judgment matrix CI=0.136, CR=0.0894<1, so it passed the consistency test. We used MATLAB to calculate the weight of each indicator, and the weight calculation results w_{ij} are shown in the Fig.2.

The proportion of the i −sample value under item to the index:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \binom{i=1,\dots,n}{j=1,\dots,m} \tag{4}$$

The entropy value of each index is calculated as e_j by using the proportion of sample value to the index:

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$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \text{ , } j = 1, \dots, m \tag{5}$$

Where $k = \frac{1}{\ln(n)} > 0$ satisfy $e_j \geq 0$.

Calculating information entropy redundancy (difference):

$$d_j = 1 - e_j \quad j = 1, \dots, m \tag{6}$$

Calculating the weight of each indicator:

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \quad j = 1, \dots, m \tag{7}$$

We use MATLAB to calculate the weight w_{2j} as shown in the Fig.3.

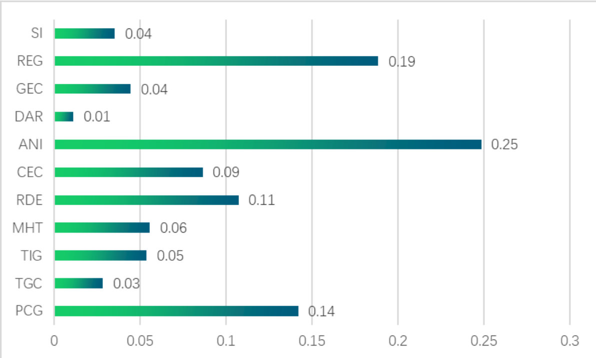

Figure 3: The weight of entropy methods

2.2. Model Establishment

In combination with the matrix Z after data normalization, there were n objects to be evaluated and m evaluation indicators.

Defining the distance between the ith (i=1,2...n) evaluation object and the maximum value:

$$D_i^+ = \sqrt{\sum_{j=1}^{m} (Z_j^+ - z_{ij})^2} \tag{8}$$

Defining the distance between the ith (i=1,2...n) evaluation object and the minimum value:

$$D_i^- = \sqrt{\sum_{j=1}^{m} (Z_j^- - z_{ij})^2} \tag{9}$$

According to the above calculation, the unnormalized score of the ith (i=1,2...n) evaluation object can be obtained:

$$S_i = \frac{D_i^-}{D_i^- + D_i^+} \tag{10}$$

The final result S is shown in Fig.4.

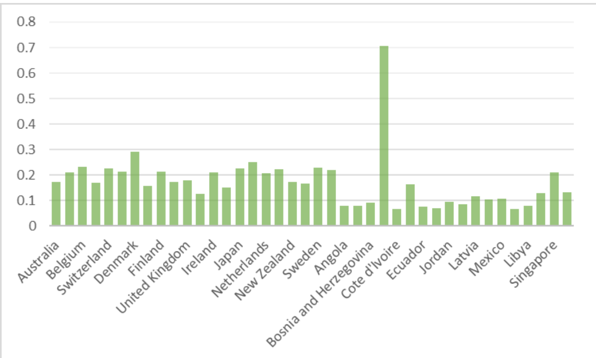

Figure 4: Global equity score for 40 countries

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After we established the global equity measurement model, we applied the date of 40 randomly selected countries into the model, and the relative equity weight per capita of 40 countries was visualized for the final calculation result of the model, which can be shown in Fig.5.

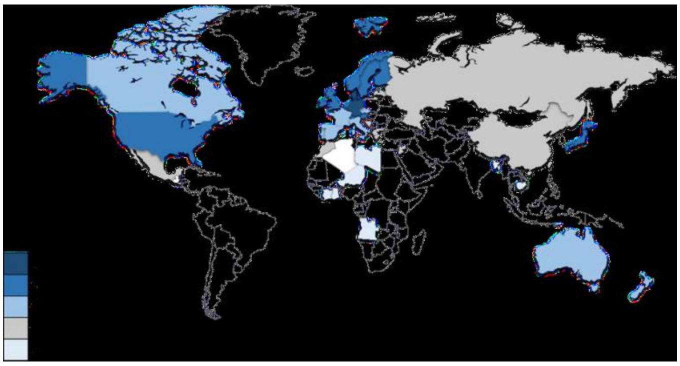

Figure 5: Global equity model application visualization

From Fig.5, we can conclude that in the implementation in countries with high global equity contribution more focused on Europe. From the perspective of European history and regional location, the "first round of modernization" started in European countries, among which Denmark, The United Kingdom, Sweden, Germany and other European countries took the lead in entering the stage of modernization, which is inseparable from their geographical location [4]. Denmark, for example, is located near the sea. As early as the 18th century, Denmark extensively participated in Atlantic trade, and its shipping industry and overseas trade were very developed. Its merchant fleet was second only to Britain in Europe, and it had a sizeable fleet. Up to now, Denmark has an extremely perfect social welfare system [5], a highly developed economy, a very small gap between the rich and the poor, and citizens enjoy a very high quality of life. Germany is located at the crossroads of Europe, the intersection of Western Europe, Eastern Europe, southern Europe and northern Europe. In modern times, Germany was close to Britain, the birthplace of the first industrial Revolution, with obvious advantages in history and regional location. The German government also attaches great importance to the development of the tertiary industry [6]. On the one hand, it takes measures to limit the import of service trade, and on the other hand, it promotes the rapid development of the domestic service industry by means of fiscal and financial policies and industrial development policies, especially the trade, finance, insurance, tourism and exhibition industries. It's consistent with our model.

3. Asteroid Mining Equity Measurement Model

Analytic hierarchy process and entropy weight method are adopted to calculate the weight, and the final index weight was obtained through coupling as shown in Fig.6.

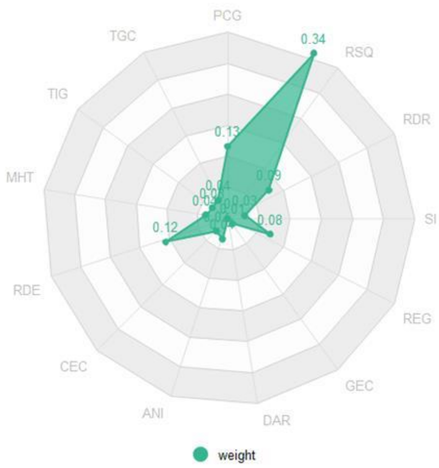

Figure 6: Comprehensive weight radar map

We join two indicators of the new again, R&D researcher (RDR) and raw steel quantity (RSQ) were included in our consideration, from which we determined a new indicator system.

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According to the scores of TOPSIS comprehensive evaluation, cluster analysis was conducted, and cluster analysis was used to obtain the following pedigrees, which is shown in Fig.7. From Fig.7, the results could be divided into three groups, those with high scores, those in the middle and those with low scores, those with high scores ranging from 0.33 to 0.2, those with medium scores ranging from 0.20 to 0.09, and those with low scores ranging from 0.09 to 0.03

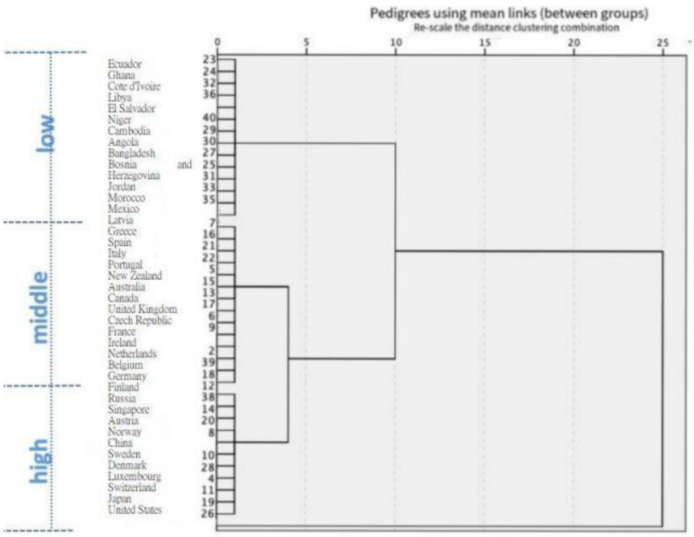


Figure 7: Average joins spectrum diagram (group)

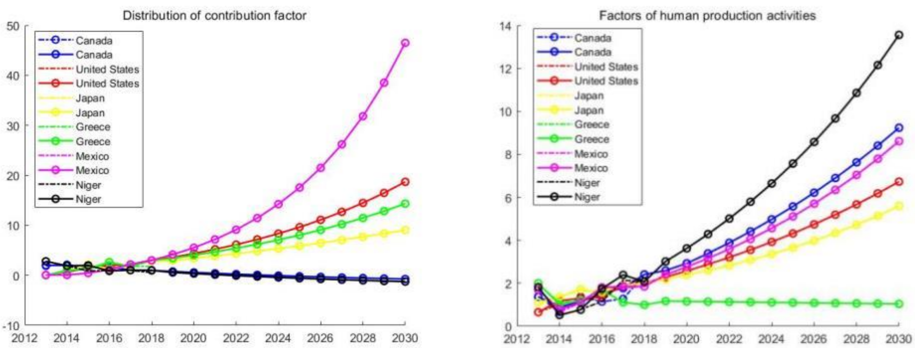
4. Impact Analysis

We studied changes in these factors to predict the possible impacts of future developments in the asteroid mining industry on global equity. Therefore, according to the principal component analysis, the four main factors that had a major impact on global equity were set as the new variables: human production activity factor, distribution contribution factor, creation factor and circulation factor.

In addition, active factors were introduced into the data processing of major factors $\xi(\xi > 1)$, which were used as the data growth coefficients to represent the abrupt impact of rich resources obtained from mining on the earth in a short period [7].

Through the analysis of the four main factors, we decided to establish a grey prediction model for correlation analysis. And through the processing of the original data, we found the law of system change and generated time series data. In order to improve the prediction accuracy, it was necessary to fit the data. Then the differential equation was established to predict the future development trend, and the GM (1,1) model was established according to the existing data.

Finally, the predicted values were tested and the accuracy of the model met the requirements. The obtained results are shown in Fig. 8(a)-(d).



(a) *(b)*

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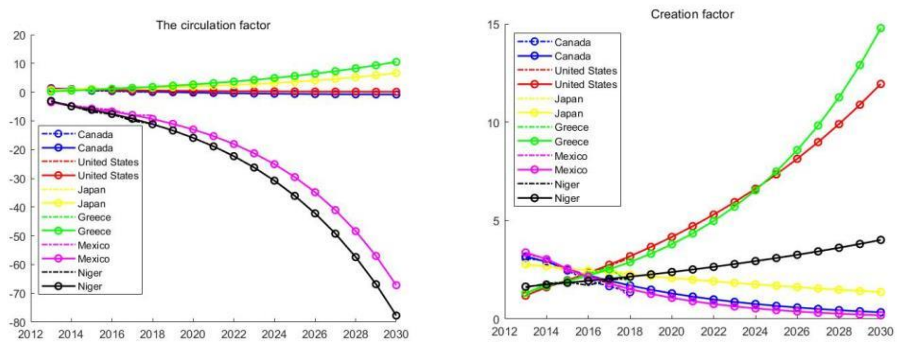

(c) *(d)*

Figure 8: GM visualization

From Fig.8, we can know that in the short term, the precious metals collected from asteroids will have a direct impact on the national economy. In addition, with the increase in the acquisition of mineral resources, the cost of microelectronics, energy storage and other fields will reduce. What's more, the abundant resources will help scientists to achieve more applications in the field of innovation.

We randomly selected from the United States for its sensitivity analysis to measure global equity model, selecting weighting of per capita GDP (PCG), research and development expenditure (RDE), sustainable index (SI), selecting the three indicators for these three indicators compared with all the 11 indexes more specific, to present more detailed suggestions for improvement.

We took the weights of these three indicators and used TOPSIS to calculate the original score, and after that, we increased GDP per capita by 10%, and we got a new score that is 3% higher than the original score, and then we added R&D spending, and we increased both R&D spending and GDP per capita by 10%, getting a new score and compared with the original score increased by 5%, we added another indicator index of sustainable development, As shown in the Fig.9, the total score increased by 1% that compared to the original score when the sustainable index increased by 10% ,this shows that sustainable development index for our model, which can effectively reflect the stability of the model.

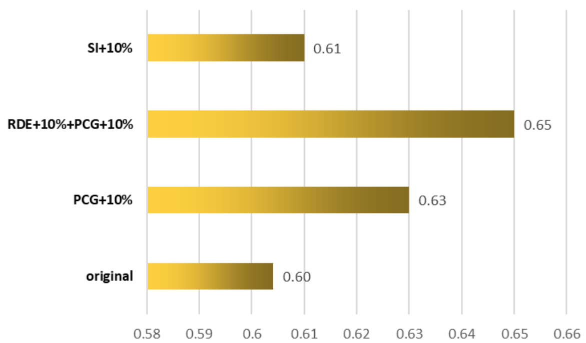

Figure 9: Sensitivity analysis visualization

5. Conclusion

In this paper, we give the definition of global equity, and based on this, we construct a model to measure global equity, and use this model to calculate the PREAW of 40 countries, and determine the impact factors of asteroid mining on global equity. In addition, according to the TOPSIS comprehensive evaluation score, cluster analysis was performed. Finally, fit the data, establish differential equations, and predict future development trends. Based on the existing data, a GM (1,1) model is established to analyze the impact of asteroid mining on global equity.

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