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Rational mining & Better future

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Abstract: *This paper addresses the issue of global equity under asteroid mining by first giving a definition of global equity: what you deserve matches what you get. Based on this, TOPSIS evaluation is used to assign scores to selected countries, and an allocation coefficient model is used to study the relationship between five indicators and country scores related to asteroid mining, and a sensitivity analysis is conducted to conclude that changes in indicators have a high impact on global equity. At this point, if global equity is to be achieved, the allocation rules must be specified with new allocation coefficients. Finally, this paper proposes scientific and constructive policies based on the above results, which are important for asteroid mining to benefit the world. The most important feature of this paper is to quantify global equity, and the established gray model and coefficient distribution model solve the difficulties of uncertainty of future asteroid mining, which are normative and easy to operate. At the same time, the established model can be extended to the scoring situation of countries based on various indicators, which can play a reference role in the formulation of future world equity policies.*

Keywords: *Global equity, TOPSIS, Grey prediction, Entropy weight method.*

1. Problem Restatement

Is asteroid mining possible? Can we profit from it? The majority of the world's nations signed the 1967 United Nations Outer Space Treaty. The treaty includes that space should be the common domain of all mankind, regardless of the level of economic or scientific development of each country. Assuming asteroid mining is possible, the first issue to be addressed in order to achieve an even distribution is to define global equity. Second, how would asteroid mining affect global equity? What are the influencing factors? Finally, what policies would the United Nations propose to increase global equity in asteroid mining?

2. Problem Analysis

For problem 1, the actual definition of "fairness" is required. The scientific rationality of the definition is the key, which is related to the establishment and solution of the whole model. First of all, it is clear that global equity does not mean that every country is allocated the same amount of resources, but we need to consider the population, economy, development and geography of each country, and select representative indicators, such as GDP per capita, land area, population base, education level, etc., to build an indicator system. The index system is quantified to find out the corresponding data of the corresponding indicators in recent decades, and then the weights of each indicator are solved, and the weights can be solved by entropy weight method, hierarchical analysis method and coefficient of variation method. Combined with gray correlation analysis and other comprehensive evaluation methods, the selected countries with global distribution are calculated and ranked, and the distribution coefficient model is obtained, the higher the score, the more resources are obtained. The higher the score, the more resources will be received. The positive and negative aspects of each indicator need to be fully considered in the comprehensive evaluation.

For problem 2, the actual problem here is to solve how to allocate the asteroid ore, which countries around the world will play a major role in the ore chain and be able to share more resources. The allocation coefficient has been modeled in Problem 1 to get the ranking of each country. However, based on the fact that mining requires technology, capital, human resources, energy and other realistic factors, it is necessary to consider adding some indicators related to mining, such as national energy reserves, technology level, etc., to recalculate the weight of each indicator and re-rank the selected countries, so as to decide the scheme of asteroid ore distribution. Comparing the rankings after adding the new indicators with the rankings obtained in question 1, we can see how asteroid mining affects global equity.

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For question 3, here we are asked to build a set of analyses to explore how global equity is affected when the mining sector changes, which is really a forecasting type of problem that predicts how the outcome will change when certain factors change in the future. Changes in the mining sector here boil down to changes in several of the indicators related to mining capacity that we selected in question 2. Based on the unknown nature of the changes in the indicators, we can predict the changes in the indicator data over the next ten years using predictive-type models such as grey forecasting, time series, interpolation and fitting, and then recalculate the final score for each country for each year, and then we can compare the changes in each country's ranking over time to get a sense of how sectoral changes affect global equity.

For question 4, here we are asked to make reasonable policy recommendations based on the results of our analysis, which is really a policy question but by no means an empty one. It requires us to make recommendations based on the model we built to measure global equity in the previous question and the limitations and unreasonable aspects of the existing Outer Space Treaty. Here we need to go through the contents of the existing relevant treaties, etc., and finally synthesize the model and make recommendations.

3. Notation

Table 1: The symbols used in the model in this paper are shown in the table below.

symbols	Definition
R&D	Number of researchers and technicians per million people
P	Population
GDP	Gross Domestic Product
S	Land area
GER	Gross Enrollment Rate
V_i	Coefficient of variation
σ_i	Standard deviation
W_i	Weights
S_i	Distribution factor (scoring)
EC	Energy consumption per capita
MRD	Mineral Resources Depletion
OMER	Ore and metal exports as a percentage of merchandise exports

4. Question 1 for solution

4.1. Model Establishment

For fairness, this paper gives the following metric: what you deserve and what you get are matched is fair. Therefore, this paper carries out a comprehensive consideration of multi-factor evaluation and finally establishes a model of distribution coefficient based on TOPSIS algorithm. Taking 24 countries in the world as an example, this model first finds representative indicators: population size, land area, GDP, gross enrollment rate, and number of researchers and technicians per million people. The data are first analyzed and the coefficient of variation is used as the basis for solving the weights, and then the distribution coefficients are evaluated comprehensively based on TOPSIS.

4.2. Correlation test

In this paper, we first conduct an analysis of covariance. If the two variables have the same trend, the covariance is positive. If the two variables have opposite trends, the covariance is negative. If the two variables are independent of each other, then the covariance is 0.

The score was found to be positively correlated with R&D P GDP S and negatively correlated with GER. This could also explain its small weight. Next, the paper proceeds to solve for the correlation coefficient. The correlation coefficient takes values between 1 and -1. 1 means that the two variables are perfectly linearly correlated, -1 means that the two variables are perfectly negatively correlated, and 0 means that the two variables are not correlated. The more the data converge to 0, the weaker the correlation is. The following is the formula for calculating the correlation coefficient.

Where rxy denotes the sample correlation coefficient, Sxy denotes the sample covariance, Sx denotes the sample standard deviation of X, and Sy denotes the sample standard deviation of y. The following are the formulas for Sx and Sy, respectively.

It can be seen that it is strongly correlated with PGDPS and weakly correlated with R&D, and it also explains the higher weight of PGDPS and lower weight of R&D.

5. Question 2 for solution

Since asteroid mining is related to many factors, we cannot consider only the five factors in problem 1. So, this paper establishes the following mining assessment model: find the representative indicators of asteroid mining: Number of researchers and technicians per million people, GDP, Energy consumption per capita, Mineral Resources Depletion, Ore and metal exports as a percentage of merchandise exports, solve the weights by entropy weight method, and then conduct mining assessment according to TOPSIS.The future vision for asteroid mining can then be represented by this mining assessment model.

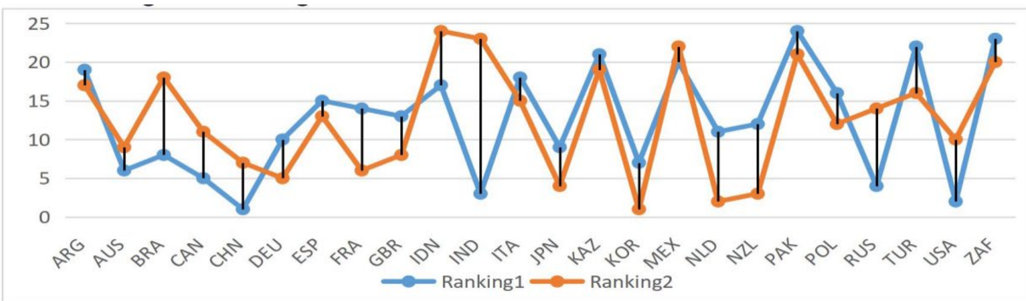

Figure 1: The changes in rankings

In this case, the black connecting line reflects the change in ranking. It is easy to see that when asteroid mining developed, it severely disrupted the current global equity, but then reformulated it with new rankings. For a possible vision of the future, simply substitute this year's data into this model to get the country scores i.e. the vision.

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It is easy to see that the absolute value of the correlation coefficient is positively correlated with the weight. For OMER, i.e., the more resources exported, the less resources are available and the lower utilization leads to a lower ranking. Therefore, the score is negatively and strongly correlated with it.

6. Question 3 for solution

In question two, five important indicators have been selected in this paper. To consider the future vision, we first have to make a gray forecast to predict the future values of the five indicators, and then bring them into the model of problem two to consider the future vision based on the scores. In this paper, we call this analysis method the vision analysis model.

It is clear that in the future, as the asteroid mining industry grows, there will be a large change in the scoring of countries. The impact on global equity when the indicator changes can be seen visually through the changes in country scores.

7. Question 4 for solution

The Outer Space Treaty was adopted by the United Nations General Assembly on December 19, 1966, and entered into force on October 10, 1967, for an indefinite period of time. The treaty, as the basic international law on outer space, sets out 10 fundamental principles for the conduct of space activities.[5]

Although the treaty is binding on the contracting parties and has positive significance for the peaceful

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development of the global space industry. However, there are many problems. First, the treaty is far from mandatory and faces enormous challenges in practice. Second, based on the global incomplete grasp of the space environment, the treaty has many legal loopholes and has become a way for some individuals and groups to make money. In this context, it is challenging for the UN to update the treaty to specifically address asteroid mining to ensure that it benefits all of humanity and drives global kilometers.

Once the asteroid mining industry has developed, it is important to consider various aspects. Such as whether the operator of the mining operation will be a national government, an international partnership, or a private company, whether the mined mineral resources will be owned by the mining country or the miner, and who will be responsible for maintaining the environment after mining. These issues are directly related to global equity, and it is important that they be clearly and exhaustively articulated and clearly defined in the treaty update. However, it is impossible and impractical to achieve absolute global equity. Fairness is relative, and what you deserve and what you get is fair. [6]

This article focuses on the hot controversial issue, the question of how asteroid resources should be allocated. In the first to third questions, we have selected 24 countries around the world as the representative of the study, and built the allocation coefficient model to get the comprehensive rating of each country, the higher the rating, the more resources you get. The allocation coefficient model has been built by considering all aspects of the country and selecting representative indicators, such as 1234, so this allocation method is fairer to some extent. In order for this allocation method to be properly implemented and to ensure that asteroid mining can benefit all of humanity, the following policy recommendations are made in this paper.

8. Sensitivity analysis

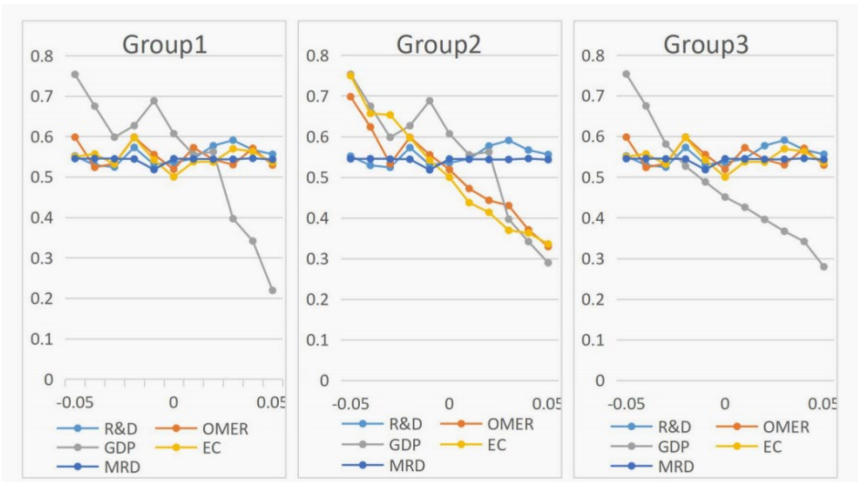

Figure 2: Sensitivity analysis

As shown in the figure, for all three data sets, the gray vision analysis model is more sensitive to GDP, and for the second data set, changes in both OMER and EC have a greater impact on the country scores. Therefore, it can be inferred that in general, the models are more sensitive to GDP. Therefore, when developing the scores, it is important to focus very much on GDP and important to consider OMER and EC.

9. Evaluation and Promotion

9.1. Advantages

(1) In this paper, when considering the impact of future steps on asteroid mining, a large amount of literature is reviewed, the parameters of the model are carefully selected, and the indicators associated with asteroid mining are especially analyzed, which makes the prediction of future impacts more refined. Through comprehensive analysis and validation, the country scores under different years in the future are given, which enhances the usefulness of the model.

(2) In this paper, the reliability of the model is further enhanced by using covariance and correlation coefficients in the step of testing the model to determine the indicator relevance of the model.

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9.2. Disadvantages

In the modeling process, only five factors related to the question are considered, and other more or less important factors are not included in the calculation. The prediction model considers less data, and some results may not be accurate enough.

9.3. Optimization and Extension

(1) Influencing factors can be considered according to very large, significant, large, and general, and more detailed scoring quantification can be performed respectively.

(2) The model in this paper can be extended to country scoring and resource allocation based on arbitrary indicators.

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