Research on Equitable Allocation of Space Resources Based on EWM-TOPSIS

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Abstract. It is a question of what happens to the issue of global equity when humans have access to space resources. This paper investigates the issue of global equity based on post-space exploration, develops a global equity model, and explores the future vision of asteroid mining based on this model. Firstly, seven global equity indicators are selected as indicators for the global equity model, and the indicators are dimensionally reduced using principal component analysis, followed by the entropy weighting method (EWM)-TOPSIS to calculate the equity index of the study population and establish a global equity model.

Keywords: Global Equity Model; EWM-TOPSIS; Asteroid Mining; Projections.

1. Introduction

Countries around the globe have signed contracts to guarantee global peace and equality. However, whether the contracts are still valid when it comes to accessing space resources is a question worth considering [1-4]. This paper considers technically, the distribution of mining work, and the distribution of benefits, based on the possibility of asteroid mining [5]. In order to address this issue, the topic will be addressed to mathematical modelling to develop a relevant model as well as to depict the impact on asteroid mining on global equity [6].

The paper first defines global equity, then selects nine countries from the database with different power characteristics as representatives for the study, selects seven indicators based on the definition of global equity and identifies three main indicators then determine their weight through objective mathematical methods, and finally builds a relevant model. On this basis, a study of asteroid mining was carried out, using different forecasting methods for certain countries, to map out the future vision of asteroid mining and its impact on the world.

2. Global equity model

2.1 Defining global equity

Global equity defined in this model refers to a quality of equity and a kind of distributive equity. When the world has set a goal, countries should do their best to make use of their own strengths to make efforts for the common goal of all mankind. The efforts mentioned here may be scientific and technological support, economic support or human resources.

No country should be excluded from paying for the goals and obtaining the results, but this does not mean the equal distribution in the absolute sense. After all, the actual situation of each country is different. The initial provision of resources should be determined according to the capacity of each country, and the final distribution of benefits should also be determined according to the payment of each country. This is "global equity".

2.2 Selection of indicators

We mainly obtain evaluation data from UCS website. Considering the integrity, accuracy and representativeness of the data, this model selects nine countries with different strength characteristics as representatives. According to the concept of global equity in the model study, seven indicators that are easy to obtain and compare are selected to reflect a country's space exploration ability. Due to the certain correlation between the seven factors, the model uses the principal component analysis method to achieve mathematical dimensionality reduction, and finally obtains three principal component factors.

Here, we mainly introduce three principal component factors:

(1) Number of space stations: as a large space building with the largest scale, the most complex technology, the most cost, the longest research and construction time and the most partners in human history, the space station can be built in only a few countries in the world. Therefore, we choose this index to better reflect a country's "space" ability.

(2) Internet penetration: today's era is an era of information exchange. The earth has become a "global village". Information communication between most people is much more convenient than in the past, and the Internet has played an irreplaceable role. Therefore, the Internet penetration can better respond to global equity issues.

(3) Number of satellites: the problem mentioned in the question is the space station, and satellites are inseparable from it. There are many kinds of satellites, such as communication, commerce, government and so on. Behind each satellite is the fairness of a country and even the world.

2.3 Defining global equity

In this section, we use principal component analysis to reduce dimension. Using SPSS software programming, the first three factors with a contribution rate of 90% are extracted as the analysis reference standard. The contribution rate of the first factor is 69.718%, the contribution rate of the second factor is 18.695%, and the contribution rate of the third factor is 10.409%. The results are as follows:

Table 1. Data results of principal component analysis

Total Variance Explained						
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% Of Variance	Cumulative %	Total	% Of Variance	Cumulative %
1	4.880	69.718	69.718	4.880	69.718	69.718
2	1.309	18.695	88.412	1.309	18.695	88.412
3	0.729	10.409	98.821			
4	0.080	1.142	99.963			
5	0.002	0.034	99.997			
6	0.000	0.003	100.000			
7	$3.843E^{-7}$	$5.490E^{-6}$	100.000			
Extraction Method: Principal Component Analysis.						

After dimensionality reduction, we get three main indicators for calculation, which are [number of space stations, Internet penetration and number of satellites].

2.4 Weight determination

(1) Data Normalization

Since the evaluation indicators contain both positive and negative ones and there exist dimensional differences among most indicators, we use range normalization to normalize data.

While analyzing all the indicators, we find that they can be divided into two types. “Symbol+” means that for the indicator, the higher, the better. Similarly, “Symbol-” means that the lower, the better. Therefore, for those indicators with “Symbol+”, we get the equation as:

$$x_{ij} = \frac{x_{ij} - min\{x_{1j}, \cdots x_{nj}\}}{max\{x_{1j}, \cdots x_{nj}\} - min\{x_{1j}, \cdots x_{nj}\}} \tag{1}$$

As for those indicators with “Symbol-”, we get the equation as:

$$x_{ij} = \frac{max\{x_{1j},\cdots x_{nj}\}-x_{ij}}{max\{x_{1j},\cdots x_{nj}\}-min\{x_{1j},\cdots x_{nj}\}} \tag{2}$$

(2) Weight Determination

The determination of indicator weight plays an important role, which directly affects the accuracy of evaluation results. Entropy weight method is an objective weighting method. Thus, we use it to determine the weight of indicators.

First, we calculate the weight of j^{th} indicator for the i^{th} country.

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} (j = 1,2,3 \ldots \ldots m) \tag{3}$$

According to the concept of self-information and entropy in information theory, we calculate the information entropy e_j of each evaluation indicator as equation.

$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln p_{ij} \tag{4}$$

Among this $k = 1/ln(n)$, satisfy $e_j \geq 0$

Based on information entropy, we further calculate the weight of each evaluation indicator we defined before.

$$w_j = \frac{1-e_j}{n-\sum_{i=1}^{n} e_j}, j = 1,2,3 \ldots \ldots, m \tag{5}$$

Then, we assign weights to each indicator and the weight results are as follows: Number of space stations (0.398) Internet penetration (0.061), number of satellites (0.541)

2.5 TOSPIS comprehensive assessment

There are three evaluation indexes in this paper. The evaluation object is the fairness index of each country [7-8].

The specific steps of IEW-TOPSIS are as follows:

(1) The canonical decision matrix is obtained by vector programming. Let the decision matrix of multi-attribute decision making problem be

$$A = (a_{ij})_{m\times n} \tag{6}$$

Normalize decision matrix:

$$B = (b_{ij})_{m\times n} \tag{7}$$

And,

$$B = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}}, i = 1,2, \ldots, m; j = 1,2, \ldots, n \tag{8}$$

(2) Construct weighted gauge matrices

$$C = (c_{ij})_{m\times n} \tag{9}$$

The weights of the three indicators were calculated based on 6.1.2.1 IEW method:

$$w_i\{i = 1,2,3\} \tag{10}$$

Let the weight vector of each index obtained by the entropy weight method be

$$w = [w_1, w_2, w_3]^T \tag{11}$$

Then,

$$c_{ij} = w_j \cdot b_{ij}, i = 1,2, \dots, m; j = 1,2, \dots, n. \tag{12}$$

(3) Determine the positive ideal solution C^* and the negative ideal solution C^0. Let the j-th attribute value of positive ideal solution C^* be c_j^*,the j-th attribute value of negative ideal solution C^0 be c_j^0,then positive ideal solution:

$$c_j^* = \begin{cases} \max_i c_{ij}, i \text{ is the benefit attribute} \\ \min_i c_{ij}, j \text{ is the cost attribute} \end{cases} j = 1,2, \dots, n, \tag{13}$$

Negative ideal solution:

$$c_j^0 = \begin{cases} \min_i c_{ij}, i \text{ is the benefit attribute} \\ \max_i c_{ij}, j \text{ is the cost attribute} \end{cases} j = 1,2, \dots, n. \tag{14}$$

(4) Calculate the distance between each scheme and the positive ideal solution and the negative ideal solution. The distance between alternative d_i and the positive ideal solution is

$$s_i^* = \sqrt{w \sum_{j=1}^{n} (c_{ij} - c_j^*)^2}, i = 1,2, \dots, m; \tag{15}$$

The distance between alternative d_i and the negative ideal solution is

$$s_i^0 = \sqrt{w \sum_{j=1}^{n} (c_{ij} - c_j^0)^2}, i = 1,2, \dots, m; \tag{16}$$

(5) Calculate the sorting index values of each scheme (namely the comprehensive evaluation index) and it is

$$f_i^* = \frac{s_i^0}{(s_i^0 + s_i^*)}, i = 1,2, \dots, m. \tag{17}$$

2.6 SEI comprehensive indicators for evaluation——SEI

Press f_i^* arrange the advantages and disadvantages of the scheme from large to small. Finally, the score calculated by countries is substituted into the fair index.

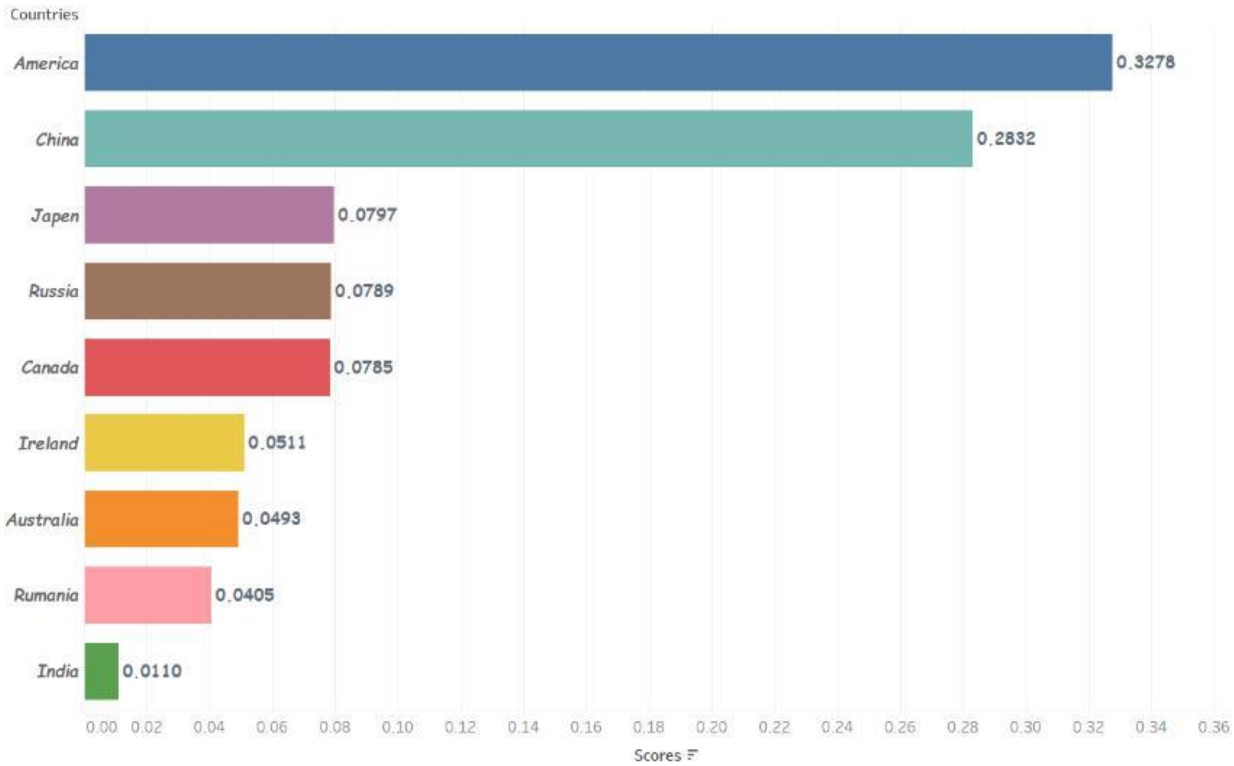

Figure 1. Comprehensive score of national equity index

It can be concluded from the observation in the figure that the equity indexes of various countries are uneven. The countries represented by the United States and China are obviously strong, while the countries represented by Rome and India are relatively backward, and the index gap between countries is large. Therefore, when this model is used to measure global equity, it can be seen that global equity is still a huge world problem, The world still faces a situation of injustice and inequality.

3. Impact of asteroid mining on global equity

3.1 Determine the criteria for asteroid mining

Regarding the future development of the asteroid mining industry, our team analyzed the scope of the problem from the following aspects and determined the index evaluation system of the asteroid mining industry to help us measure its impact on global equity.

There are three main indicators: the feasibility of science and technology, the possibility of benefit and the target of funding.

The possibility of benefit is measured by two secondary indicators: cost minimization and revenue maximization.

Benefits are the difference between revenues and costs. As costs decrease and income increases, the possibility of benefit increases. Among them, cost minimization has three three-level indicators: technology optimization cost, resource follow-up processing cost and ground human operation cost; Revenue maximization has two three-level metrics: available resource extraction value and resource detection complexity. We measure the complexity of resource exploration in terms of the asteroid's shape, resource distribution, and distance from earth.

The funding target includes three main bodies: private companies, national governments, and international cooperation organizations.

The system diagram is shown below:

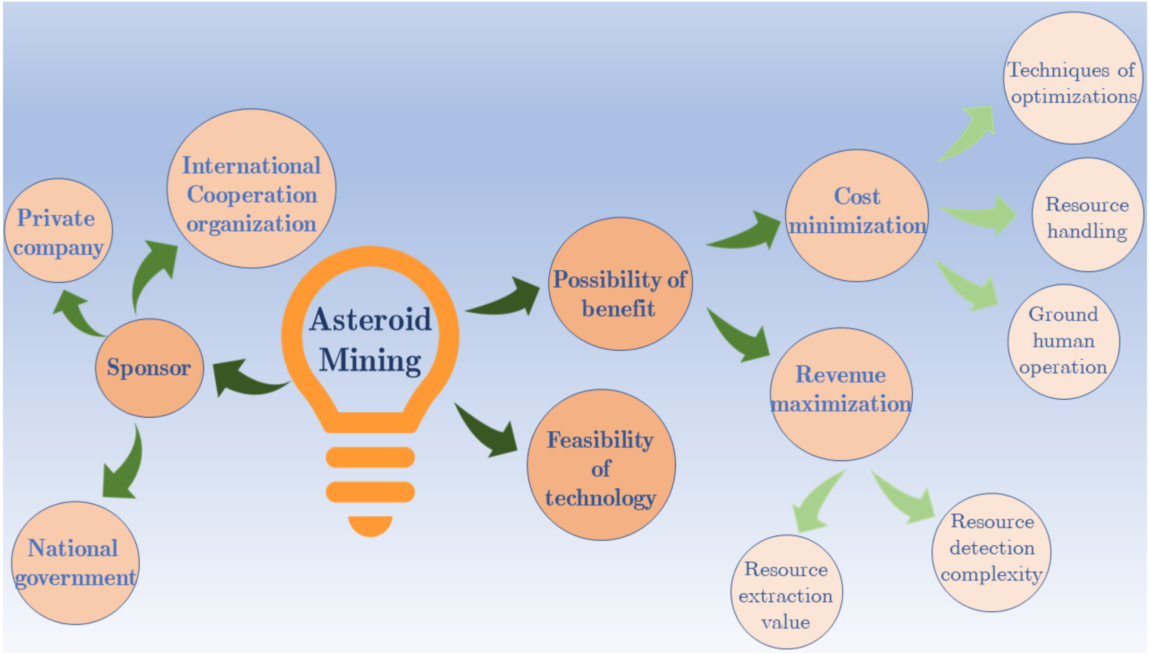

Figure 2. Index hierarchy for asteroid mining

3.2 Vision of the future of asteroid mining

Asteroid mining in the future will realize global fair, this fair is not absolute in the sense of fairness, but relatively fair to allocate resources and opportunities, regardless of the national economy and the development of science and technology level, all the countries all over the world can try their best to provide their own resources to asteroid mining industry, and also can get the corresponding benefit and reward, This will be an international topic and industry, not limited to the competition among countries in the industry, the international pursuit of win-win cooperation, which is the meaning of global fairness.

In the future, the specific situation of asteroid mining will be elaborated in detail in this paper by using the index conditions mentioned above. In addition to the feasibility of science and technology, both the possibility of benefit and the object of funding are explained by subordinate indicators. Therefore, this paper first formulates a grade judgment table for the feasibility of science and technology, as shown below:

Table 2. Scientific and technical feasibility level definition

Science and technology feasibility level			
Level	C	B	A
Asteroid shape	Structured	Unstructured	Malformed
The distribution of resources on asteroids	Single	Multiple	Complex
The distance an asteroid from the Earth	Near	Far	Farther

The future vision of asteroid mining is beautiful, and it can well reflect global equity. This paper describes the future vision of asteroid mining one by one from three main indicators, as follows:

Table 3. Future vision of asteroid mining

Vision for the future of asteroid mining		
Feasibility of technology	Possibility of benefit	Sponsor
Advanced science and technology have the ability to detect asteroids with more irregular shapes, complex resource distributions, and farther away from Earth.	Ability to minimize costs and maximize revenue. That is, the optimization of technology and the reduction of manpower use can greatly reduce the cost; The ability to detect asteroids, which are more valuable and complex to extract resources, has also greatly increased the benefits.	Asteroid mining is no longer a company or a country, but a goal and undertaking shared by all nations of the world, funded by international partners.

3.3 The impact on two-dimension analysis vision on global equity

The framework of the analysis is shown in the figure below:

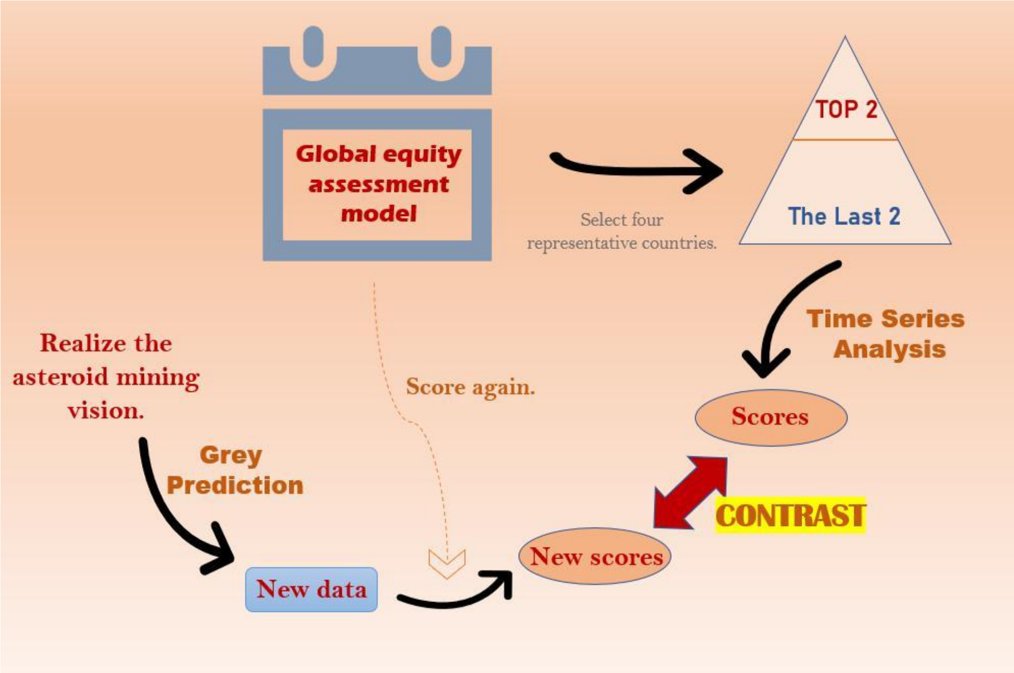

Figure 3. Framework for the study of the impact of asteroid mining on models

According to the above the reasonable assumption that an asteroid mining after reaching the future vision to a larger impact on equity index, we reasonable speculation when an asteroid mining industry matures, the feasibility to achieve higher level of science and technology, benefit maximum likelihood, and funded by the international cooperation agency, fair index will be growing exponentially, In addition, there is a coordinated and uncertain relationship among various indicators of system behavior, so grey prediction is used in this analysis [9].

Using the collected values of the three indicators of the four countries from 2015 to 2021 and MATLAB programming, the gray prediction and time series analysis of the three indicators of the top two and the bottom two countries, the United States, China, Romania and India, were conducted respectively [10]. Residual test or grade ratio test was conducted for the predicted values obtained from each gray prediction. Among them, 9 times can meet the higher requirements, 3 times can meet the general requirements, the overall meet the requirements of grey prediction.

Visualized the results of the two predictions,

The comparison of the four countries before and after asteroid mining is shown below:

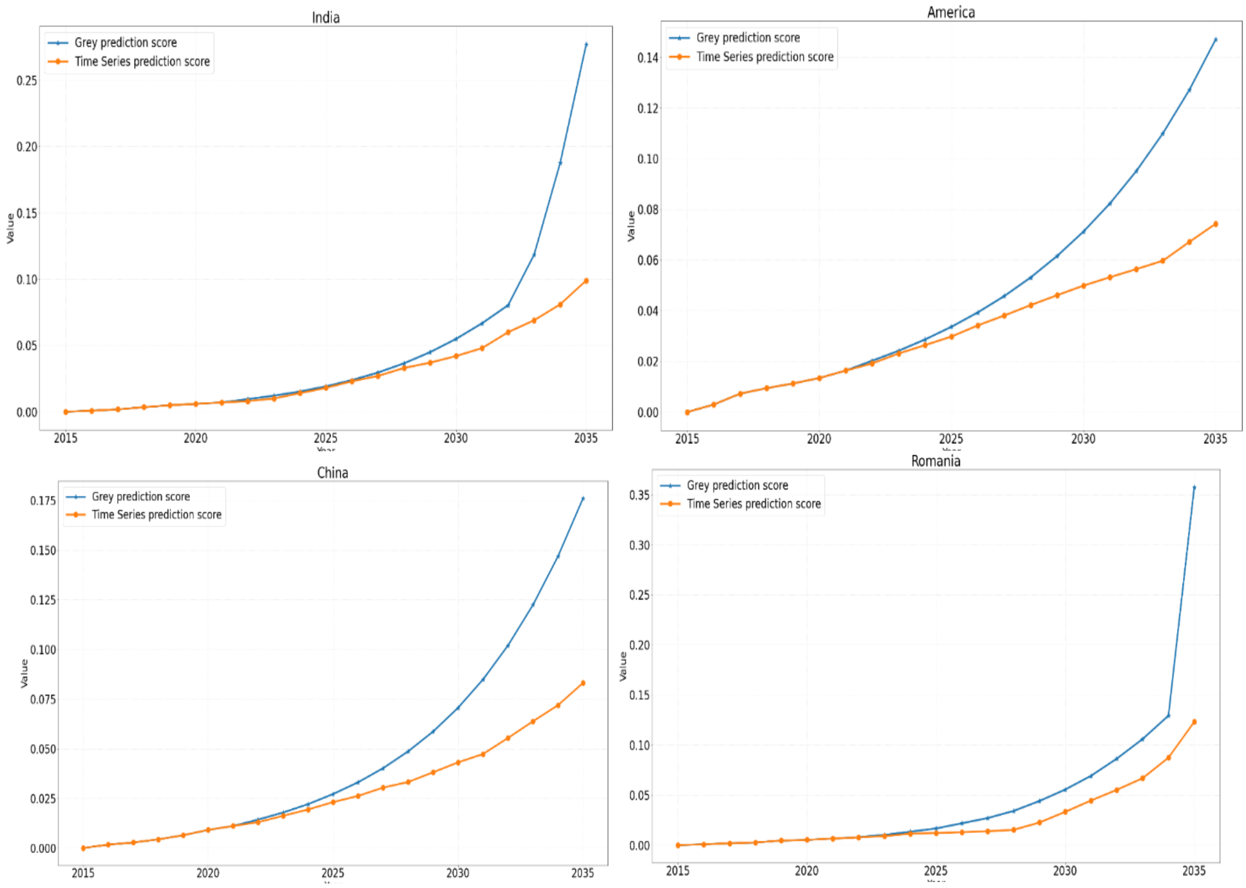

Figure 4. Visualization of four representative countries' grey and time series prediction results

Thus, the realization of the future vision of the asteroid mining industry plays a significant role in promoting the realization of global equity, and the closer the asteroid mining is to the target, the higher the global equity index will be.

In addition, countries that have made some achievements, such as the United States and China, have more input and more output. Countries that started from scratch have also made great progress, reaching the middle level of the United States and China, which plays a significant role in promoting global equity.

Win-win cooperation, rational distribution of resources and opportunities, so that the global human development together, global fairness can be reflected to the maximum extent, the fairness index is greatly improved than the asteroid mining industry was not developed.

4. Conclusions

This thesis introduces the concept of global equity, then uses principal component analysis to dimensionally reduce the indicators, followed by entropy weighting to calculate an equity index, and finally validates the applicability of the model with known data, with the results showing that the current global inequality problem remains huge.

Three indicators for asteroid mining were selected based on industry characteristics, and then the impact of the top and bottom countries on the equity index was simulated using grey forecasting and time series forecasting models based on the SEI model. The results show that the realization of the future vision of the asteroid mining industry plays an important role in contributing to the achievement of global equity, proving win-win cooperation and rational allocation of resources and opportunities for global human development.

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