Global Equity Measurement Model

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Abstract. In this paper, we calculate the weight of each index through the entropy weight method and perform a regression analysis to obtain the WRSR value representing the comprehensive strength index (CSI). In addition, based on the salary distribution model, we use the linear asteroid mineral investment model to look forward to the future development trend. Finally, we use the gray prediction model GM(1,1) to predict the proportion of each condition in the next 10 years, and the future change with time is obtained by polynomial fitting.

Keywords: Global equity, asteroid mining, polynomial regression model, rank-sum ratio (RSR), analytic hierarchy process (AHP), gray prediction model (GM(1,1)).

1. Introduction

Facing the shortage and even depletion of the Earth's resources, it has become a major trend to develop and utilize the Earth's extraterrestrial resources for all mankind. Most nations signed onto the United Nations' Outer Space Treaty of 1967, agreeing on using space resources, and all mankind should share the benefits to promote global peace and reduce inequality. Under the support of international space law, many countries have become increasingly proficient in using space resources, launched satellites, and established space stations, which vigorously developed the aviation science business. From the perspective of the interests of all mankind, we should consider how to ensure global equity and make space resources can be exploited peacefully, orderly, safely.

When we focus on the asteroid mining project, there are approximately 15,000 asteroids of various sizes within a radius of 50 million kilometers centered on the Earth. Asteroids contain unimaginable reserves of precious metals, nickel, iron, and rare metals. The total value of the resources in the current space rocks is equivalent to about $100 billion per person. If these resources are exploited, they will lay an important material foundation for the perpetual development of human civilization.

Due to the lack of institutional security and global equity, countries are not yet able to achieve quantitative exploitation in terms of technology and funding. The four key aspects of research urgently needed for space mining are resource exploration, mining intelligent robot platform design and manufacturing, resource exploration and extraction, and mining space security and utilization [1]. In order to solve the above problems, the ultimate global equity can only be achieved if all countries work together to cooperate in the future and commit to contributing to the well-being of all humanity.

This paper establishes a Rank Sum Ratio Comprehensive Evaluation Model (RSR), which divides the evaluation dimension into 8 indicators, evaluates the comprehensive strength of continents and countries, and ranks them. In addition, we discuss the rational allocation of mineral resource utilization and analyze how the implementation of asteroid mining affects global equity. Finally, the grey forecast model GM(1,1) was used to re-evaluate the inputs for the next 10 years in the three regions by normalizing the data.

2. Model Establishment and Solutions

The criteria for making a grade are based on historical performance and regional characteristics, and the rank and ratio comprehensive evaluation model (RSR) is used to solve the grade in the definition of equity [2]. Based on the nine elements that constitute national strength by the American scholar Hans Joachim Morgenthau, we select 8 evaluation indicators to measure a total of 16 typical countries in 6 continents and each continent, calculate the weights of each indicator through the entropy weight method and conduct regression analysis to obtain the WRSR values to determine and rank the Comprehensive Strength Index (CSI) respectively, so as to realize the establishment and solution of the model, which includes the following steps [3].

To facilitate subsequent arithmetic, the dimensions are represented using symbols as follows in Fig. 1.

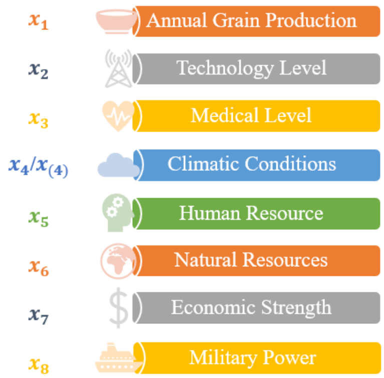

Figure 1. Indicator interpretation

The cost-based indicators are transformed into efficiency indicators can be expressed as:

$$x_4 = \frac{1}{x_{(4)}} \tag{1}$$

The data normalization expression is:

$$x_{ij} = 0.998\frac{x_{ij} - min\{x_{1j}, \cdots x_{nj}\}}{max\{x_{1j}, \cdots x_{nj}\} - min\{x_{1j}, \cdots x_{nj}\}} + 0.002 \tag{2}$$

The weight p_{ij} of the indicator value of the *i* th program under the *j* th indicator can be expressed as:

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

The information entropy value of the *j* th indicator can be expressed as:

$$e_j = -k \sum_{i=1}^{n} p_{ij} \, ln \, p_{ij}, \quad k = \frac{1}{\ln(n)} \tag{4}$$

The information entropy redundancy of the j th indicator can be expressed as:

$$g_j = 1 - e_j \tag{5}$$

The weight of the j th indicator can be expressed as:

$$w_j = \frac{g_j}{\sum_{j=1}^{m} g_j} \tag{6}$$

The formula of rank-sum ratio can be expressed as:

$$WRSR_i = \frac{1}{n} \sum_{j=1}^{m} w_j R_{ij}, i = 1,2, \cdots, n \tag{7}$$

Where w_j is the weight of the *j* th evaluation index.

The linear regression equation obtained from the classification of the six continents is:

$$WRSR_{1i} = -0.1375 + 0.1363 \times probit_{1i} \tag{8}$$

The linear regression equation obtained from the classification of 16 countries is:

$$WRSR_{2i} = -0.0794 + 0.1189 \times probit_{2i} \tag{9}$$

For the 6 continents, we follow the "percentages and probability units comparison table" to find their corresponding probability unit $\mathrm{probit_i}$ values, and divide the seven continents into three classes, as shown in Table 1.

Table 1. Grade division of 6 continents

Classes	$probit_{1i}$	$WRSR_{1i}$	Result
Weak	<=4	<=0.4077	Oceania
Medium	4~6	0.4077~0.6803	Asia South America North America Africa
Strong	>=6	>=0.6803	Europe

The ranking of the 6 continents is shown in Table 2.

Table 2. 6 continents comprehensive strength ranking

Continents	$probit_{1i}$	$WRSR_{1i}$	Rank
Europe	6.7317	0.780031	1
Asia	5.9674	0.675857	2
North America	5.4307	0.602704	3
Africa	5	0.544	4
South America	4.5693	0.485296	5
Oceania	3.989	0.406201	6

For the 16 countries, we get the final $\mathrm{WRSR_{2i}}$ values in the following table, with the grades and rankings, are shown in Table 3 and Table 4.

Table 3. Grade division of 6 continents

Classes	$probit_{2i}$	$WRSR_{2i}$	Result
Weak	<=4	<=0.3962	Australia Canada
Medium	4~6	0.3926~0.634	Brazil, Spain, India, China, South Africa, Nigeria, France, UK, Morocco, New Zealand,Argentina
Strong	>=6	>=0.634	USA Germany Japan

Table 4. 16 countries comprehensive strength ranking

Countries	$probit_{2i}$	$WRSR_{2i}$	Rank
Japan	7.1539	0.771199	1
Germany	6.5341	0.697504	2

USA	6.1503	0.651871	3
Argentina	5.8871	0.620576	4
Morocco	5.6745	0.595298	5
NewZealand	5.4888	0.573218	6
UK	5.3186	0.552982	7
France	5.1573	0.533803	8
Nigeria	5	0.5151	9
SouthAfrica	4.8427	0.496397	10
China	4.6814	0.477218	11
India	4.5112	0.456982	12
Spain	4.3255	0.434902	13
Brazil	4.1129	0.409624	14
Canada	3.8497	0.378329	15
Australia	3.4659	0.332696	16

3. Analysis Process

3.1 The future of asteroid mining

We use AHP to obtain the weights of three key indicators, as shown in Fig. 2 [4].

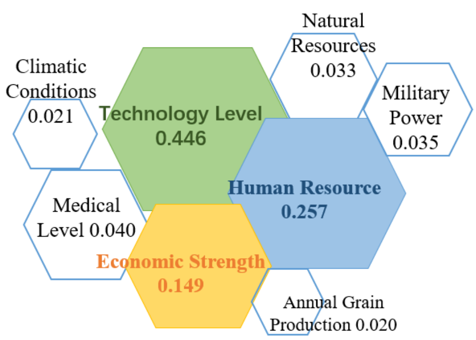

Figure 2. AHP key indicators

After reviewing the relevant information and reasonable assumptions and corresponding to the key indicators, we envisage that the project contains 3 Conditions: Technical Operation, Scientific Research Personnel, and Investment Funds, as shown in Fig. 3.

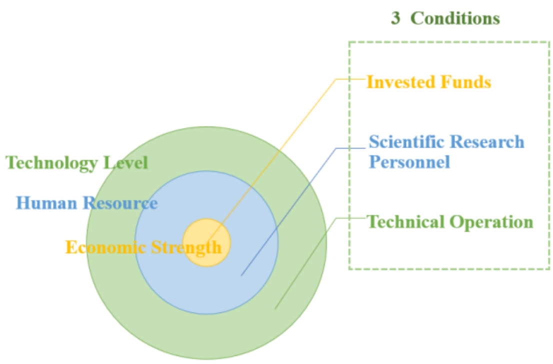

Figure 3. Three conditions schematic

3.2 Implementation Process and Impact

The asteroid mining project is envisioned to have two phases: development investment and resource allocation after successful mining.

According to the model of problem 1, the comprehensive strength index of the country is calculated, and the final values can be obtained to divide the countries into three classes. Then, the participating investment subjects are divided into two parts. The first part is the stronger countries and can actively make substantial contributions to asteroid development, which we call Class I countries and the second part is the weaker countries, which can hardly play a larger role in the asteroid resource development project and can only participate through some simple inputs, which we call Class II countries. The second part is the weaker countries, which can only participate through some simple inputs. In order to maintain the fairness of each country's interests, the final resource allocation will be different for Class I and Class II countries [5].

Determine the input cost share of the above 3 conditions in the whole project as p_1, p_4 andp_3. ($p_1 + p_2 + p_3 = 1$). Based on the data of the strengths and weaknesses of Technology Level, Human Resource and Economic Strength of the 16 countries in problem 1, divide the 3 aspects of Technical Operation, Scientific Research Personnel, and Investment Funds into 3 levels respectively, with high levels representing strong technology, high quality of talent, and more funds, implying high returns, and therefore given greater weights to reflect their greater importance. Class I countries can choose the corresponding portfolio to invest in the 3 levels of the 3 aspects. For Class II countries, they can choose to invest in Level IV outside of the other 3 levels, and considering their weaker overall strength. They can participate in the program by making a smaller investment as appropriate. The resulting asteroid mining investment model is shown in Fig. 4.

After the asteroid mineral resources are successfully mined, the investment model divides the resources into two parts and uses the 80/20 efficiency law (Paret's Law) to form the "80/20 efficiency law" for the resources, which means that the resource allocation should be tilted to Class I countries. They allocate 80% of the resources in proportion to their inputs [6]. The remaining 20% will be set up as a foundation for Class II countries to allocate the resources in proportion to their input in Level IV, and finally determine the mineral resources of asteroids for each of the two classes of countries in their individual parts [7]. This process can be demonstrated in Fig.5. Through cooperation, countries will also have trade between countries after allocating resources. Countries with different needs can benefit from trade exchanges, which will somehow drive the economic development of each country, promote friendly relations between countries, and increase global equity [8].

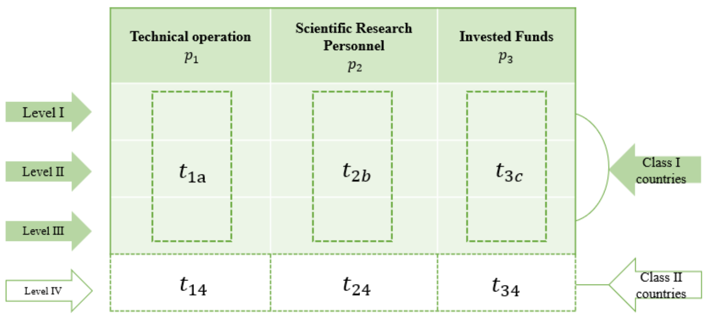

Figure 3 Asteroid mining investment mode

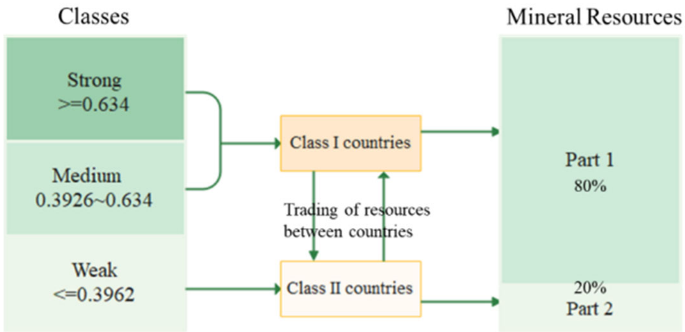

Figure 4 Resource allocation diagram

Class I countries:

The amount of inputs in the investment development phase is expressed as:

$$t^i = p_1 t_{1a}^i + p_2 t_{2b}^i + p_3 t_{3c}^i \tag{10}$$

Where *a, b, c* can all take the values of 1,2,3, respectively, indicating Level I, Level II, Level III.

The final percentages of inputs can be expressed as:

$$q_i = \frac{t^i}{\sum_{i=1}^m t^i} \tag{11}$$

Where m is the total number of Class I countries participating in the asteroid investment project.

The final amount of resources obtained is calculated by :

$$F_i = q_i \times 80\% \times y \tag{12}$$

Class II countries:

The amount of inputs in the investment development phase is expressed as:

$$t^j = p_1 t_{14}^j + p_2 t_{24}^j + p_3 t_{34}^j \tag{13}$$

where *a, b, c* can all take the values of 1,2,3, respectively, indicating Level I, Level II, Level III.

The final percentages of inputs can be expressed as:

$$q_j = \frac{t^j}{\sum_{j=1}^n t^j} \tag{14}$$

Where n the total number of Class II countries participating in the asteroid investment project.

The final amount of resources obtained is calculated by:

$$F_j = q_j \times 20\% \times y \tag{15}$$

4. Model Improvements

Using the grey prediction model GM(1,1), we obtained the predicted values of technical operations, scientific researchers, and investment funds for 20 years from 2010 to 2029. Not only did the values of these three conditions change, but also the weights (p_1, p_2,p_3) has also changed, and the importance of these three conditions is different from that obtained using AHP [9].

Introducing the whitening equation, the general solution of the obtained sequence can be expressed as:

$$\widehat{x_k^{(1)}} = \left(x_1^{(0)} - \frac{b}{a}\right) e^{-\alpha(k-1)} + \frac{b}{a}, \quad k = 2,3,\dots,10 \tag{16}$$

The general solution of the sequence is simplified to the original sequence, and the prediction function is obtained as:

$$\widehat{x_k^{(0)}} = \left(x_1^{(0)} - \frac{b}{a}\right) e^{-\alpha(k-1)}(1 - e^{a}), k = 2,3, \ldots ,10 \tag{17}$$

According to the gray prediction model, the results indicate that we obtained the predicted values of science and technology input, personnel input, and capital input for the next ten years, respectively, as shown in Fig. 6, Fig. 7, and Fig. 8.

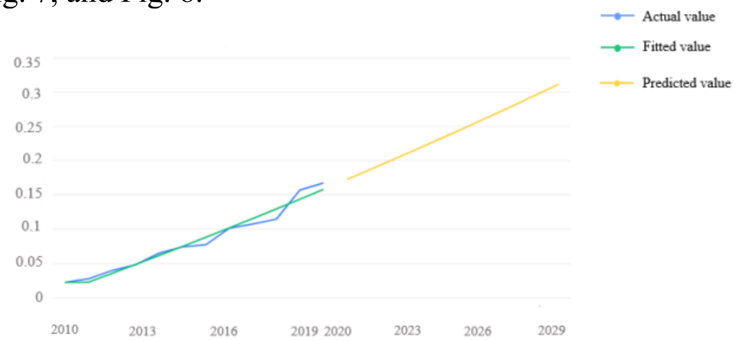

Figure 6. GM (1, 1) of the next ten years of science and technology inputs

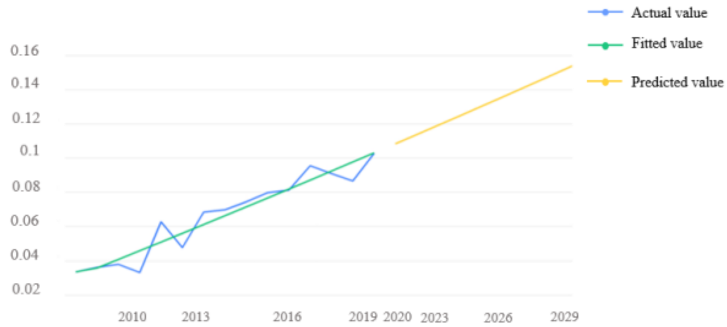

Figure 7. GM (1, 1) of the text ten years of personnel inputs

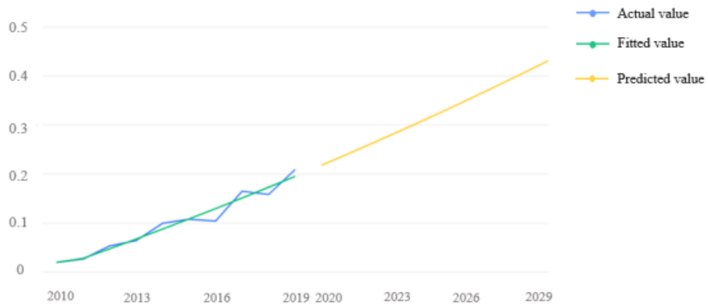

Figure 8. GM (1, 1) of the next ten years of funds inputs

We also obtained the process of changing the weights of these three indicators, as shown in Fig.9.

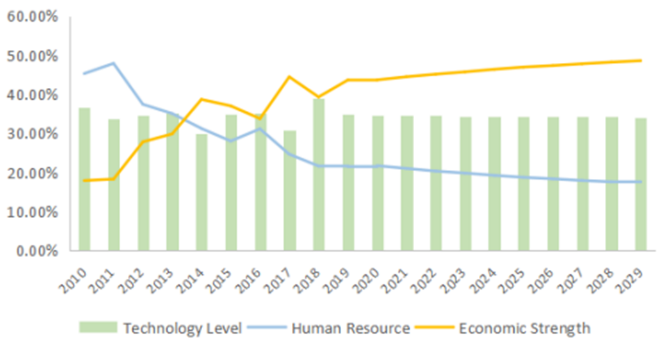

Figure 9. Changes in 3 condition inputs in the next 10 years

From Fig.9, we can see that the proportion of the three in 2010 is 36.79%, 45.28%, and 17.92%, and the proportion of the three in 2029 is 34.10%, 17.32%, and 48.57%, the development of the next ten years is that the proportion of science and technology inputs is stable, the proportion of personnel inputs may decrease and stabilize year by year, and the proportion of capital may increase year by year and surpass Science and technology inputs.

Meanwhile, we see that the changes of the two indicators, the percentage of personnel and the percentage of funds, are almost representative of the changes of the conditions in the whole asteroid excavation project, so we use polynomial fitting to form Fig. 10 to appreciate the trend of the two more intuitively and clearly.

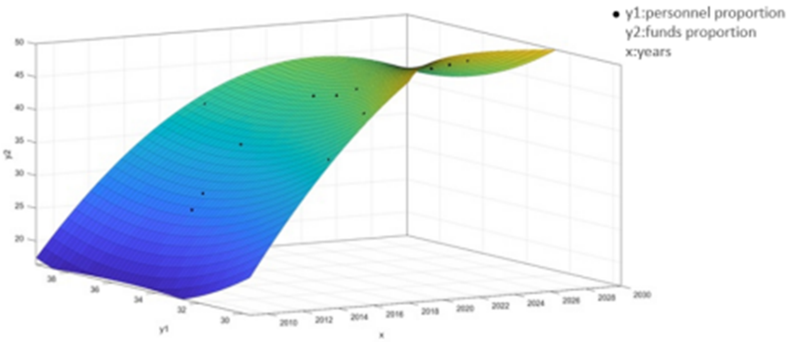

Figure 5. Trend of personnel and funds

5. Implement Policies

According to the historical data and the latest reports, about 6 international organizations have conducted space exploration and invented space objects, which contain more than 40 countries. In the Outer Space Treaty signed by various countries in 1967, it has been clearly stated that the exploitation of outer space resources should follow the principle of common interest of all mankind. Due to the limitations of their respective technological development, there have been 67 committees in recent years for those involved in the use of outer space. However, the number of countries using outer space has not changed for many years, so cooperation in the developing outer space resources

Assuming that the United Nations is currently revising the Outer Space Treaty for the asteroid mining project, in order to ensure that the benefits of asteroid mining are shared by all of humanity and promote global equity, based on our study of the above three issues and the model we have developed, our recommendations to the United Nations are given here as follows [11].

Firstly, policies need to be developed to increase regulations regarding asteroid mining.

The development of asteroid resources can be done by signing agreements to increase participation in cooperative projects. Agreements should be clearly defined in cost inputs and profit sharing to facilitate their implementation and monitor active participation by countries. In response to possible problems with the agreement, the concept of how to define the launching country should be determined as soon as possible, and the regulations on profits, compensation and maintenance of cooperative asteroid launches should be determined to prevent members of the agreement from pursuing their interests with a large goal and the emergence of military use of outer space. International cooperation will increase material profits and enhance the exploration of the universe for all mankind and have a positive effect on the development of human civilization. It is hoped that this approach will allow individual countries to agree on the goal of significantly increasing the number of space objects and the total number of countries launching asteroids.

Secondly, in terms of specific regulations, we need to understand that conducting an outer space exploration requires technical operations, scientific personnel, and investment funds, and proper consideration of pending issues arising from special factors such as the occurrence of accidents outside the launch site and compensation.

Our recommendations are presented in the following 5 aspects and shown by Fig. 11:

Figure 11. Schematic diagram of policy recommendations

We analyze the polynomial fit model to obtain a fit function:

$$y = 66.5x^2 + 149.5x + 708 \tag{18}$$

where the goodness of fit of 1. Based on the fit function, we can estimate the future time used by the countries to reach the expected pursuit for the benefits of this project [12].

In conclusion, we need to clarify that we should maintain cooperative relations between countries in the exploration of outer space and that each country should actively assume its responsibilities and obligations in this project. During this period, we need to continue to implement human resources training programs and increase investment in asteroid mining research and development, as well as to set up relevant guarantee treaties and establish reasonable compensation to reduce the risk of failure of national investments to form a global fair asteroid mining project.

6. Sensitivity Analysis

Because the total global investment in future asteroid excavation and exploration projects is an important indicator of whether the project benefits all of humanity, we chose the forecast value of $31.8 billion in 2030 as the standard, changed the value of the quadratic term coefficient p1 to 66.5 ± 0.15, and calculated again to obtain the error as shown below by Figure 13.

When p1 is changed in the range of 0 ± 0.15, it can move on the curve of 0.2%. The results are what we want, and the model passes the sensitivity test.

7. Conclusion

In this paper, we propose a global equity measurement model that establishes 3 important factors in the asteroid investment model and considers the weight ratio of the 3 factors. Specifically, according to the degree of change of each index value, the entropy weight method is used to determine the index weight. After considering the asteroid mining project, we use the analytic hierarchy process to subjectively increase the weight of technology, personnel, and funds, making up for the entropy weight method in determining the weight. It is easy to ignore the insufficiency of the subjective intention of decision-makers when making weights. Finally, the future development trend is prospected by using the method of RSR combined with parameter analysis and grey forecasting model.

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