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Research on Global Equity Evaluation and Exploitation and Investment Allocation of Asteroid Mineral Resources

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Abstract: *At present, the huge prospect of asteroid mining makes the investment and benefit allocation of asteroid mining become a hot issue. This study discussed how to exploit and distribute the mineral resources of asteroids fairly. A method to measure global equity was put forward, and four indicators that affect global equity: extreme poverty, war instability, north-south gap and carbon emissions per capita were identified. Then, the analytic hierarchy process method was used to give proper weights to the deter-mined factors and pass the consistency test, and then a global equity evaluation model was established. With reference to aerospace technology and science fiction technologies such as space elevator, a mining and investment income allocation model was developed according to economic principles. The division of labor in different stages of mining industry and its possible influence on global equity were preliminarily qualitatively analyzed. The results show that the established mining and investment income allocation model will make the whole world realize better equity in the later stage of mining. This study provides a good idea for the exploitation and utilization of asteroid mineral resources and the distribution of investment income in the future.*

Keywords: *Asteroid mining; global equity; Global equity evaluation model; Mining and investment income allocation model*

1. Introduction

In recent years, with the progress of science and technology and economic development, commercial and civil aerospace, such as the SpaceX, has appeared in the public's field of vision [1-2]. Due to the limitation of earth resources, asteroid exploitation and other space re-sources utilization have become a hot topic. Mineral resources on asteroids in space are good and abundant human resources that can be exploited and utilized [3]. Although there are many difficulties in exploiting the mineral resources of asteroids with existing technologies and funds, some countries are still trying and have made some gains. It can be predicted that the precious mineral resources of asteroids will be brought back to the Earth in the near future. Therefore, more perfect laws are urgently needed to regulate the exploitation of asteroids in the future [4]. In addition, how to allocate the resources of asteroids can meet global equity and make all countries in the world have the opportunity to benefit from the asteroid mining industry, which is also an important issue to be considered at present.

The goal of this research is to develop a global equity evaluation model that is as fair as possible by defining a method to measure global equity. On this basis, to establish a reasonable asteroid mining and investment income allocation model, so as to promote the global equity and benign development of asteroid mining and allocation in the world.

2. A global equity evaluation model

2.1. Determination of evaluation indicators

Based on the analysis of previous research literature, this study summarized the indicators that affect global equity as follows: extreme poverty, war instability, north-south gap and the global environmental consumption level [5]. In order to facilitate the quantification of the follow-up analytic hierarchy process (AHP) method, four dimensionless indicators, namely extreme poverty, war instability, north-south gap

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and carbon emissions per capita, were used to characterize the above four influencing factors.

2.2. Quantization of indicators

2.2.1. Extreme poverty

Extreme poverty is also known as the poverty line. A unified poverty line was put forward by the World Bank in 2015, that is, the minimum daily consumption of 1.90 dollars. In order to nondimensionalize the number of people living in extreme poverty and better compare the global population, the proportion of people living in extreme poverty is called extreme poverty rate. By studying the changes of extreme poverty rate from 1800 to today, it was found that it had gradually decreased from 85% in 1800 to 9% today [6]. The extreme poverty rate is un-desirable to society, and the smaller this index is, the better global equity will be.

2.2.2. War instability

When discussing the obstacles of war to the development of countries and the world, it is necessary to distinguish the harmfulness and influence of different types of wars. For this reason, countries can be roughly divided into four levels, from the most destructive to the least destructive: level 1 is a country with national wars, level 2 is a country with local and disputed regional wars, level 3 is a country with foreign wars, and level 4 is a country with-out wars.

Only the highest ranking is recorded for a country with many wars. These levels need to be weighted, so that the distribution weights of level 1, level 2, level 3 and level 4 are 3, 2, 1 and 0 respectively. Then add them together. Considering that too many wars will destroy the system, it is necessary to find the up-per limit of this index to make the war instability index dimensionless. Therefore, assuming that the war instability index reached the peak of 130 during World War II, then the war in-stability index is:

$$WII = \frac{3x_1 + 2x_2 + x_3}{130} \tag{1}$$

Where X_n represents the number of countries at the n-th level.

So far, the dimensionless processing of all indexes has been completed.

2.2.3. North-south gap and carbon emissions per capita

Internationally, Gini coefficient between 0 and 1 is commonly used to represent the gap between the rich and the poor in a country. The Gini coefficient is an index put forward by the Italian economist Gini, which is applied to express the average degree of distribution according to Lorenz curve. The smaller the Gini coefficient, the smaller the gap between the rich and the poor.

Zhang Jianhua put forward a simple Gini calculation formula [7], the process is as follows: the n elements of array A are sorted from small to large, called as A_i, k is selected as an integer from 1 to n, $X=k/n$, $y = \sum_{i=1}^{k} A_i \Big/ \sum_{i=1}^{n} A_i$ and then this function and $y=X$ function put into the area S. The expression of Gini index is as follows:

$$Gini = 2S \tag{2}$$

This calculation formula is more convenient to process data and the calculation results are more intuitive, so this calculation method is adopted in the research.

For the north-south gap and the gap between environmental consumption, we can use this model for reference to change the array of national personal income into the array of GDP per capita and carbon emissions per capita of different countries, so as to evaluate the north-south gap and the gap between environmental consumption. According to the golden ratio, the international safety line of Gini coefficient is set at 0.4. Social conflicts are likely to occur due to the large gap between the rich and the poor after exceeding this standard. Therefore, these two factors will have greater weights in the subsequent modeling.

2.3. An evaluation model based on the analytic hierarchy process method

Analytic hierarchy process (AHP) is a method of qualitative analysis and quantitative calculation [8-9]. The decision-making problem of this method is divided into three levels [10]: the top level is the

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objective level, that is, an object to be evaluated, here is global equity; The middle layer is the criterion layer, that is, the impact indicators of selecting and evaluating objects, there are the four quantitative indicators mentioned above; The bottom layer is the plan layer, that is, the alternative plans, which includes four different years. The hierarchical structure established in the study is shown in Figure 1 below.

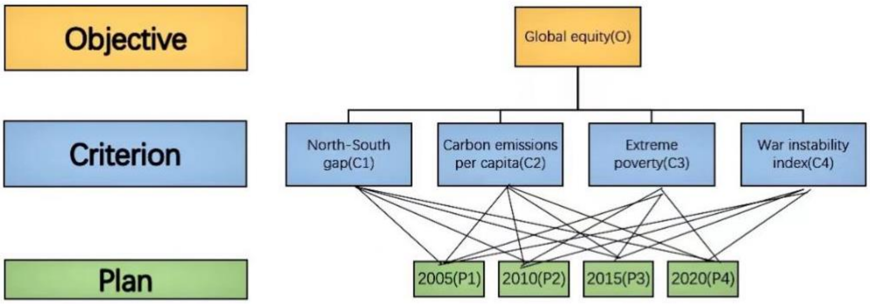
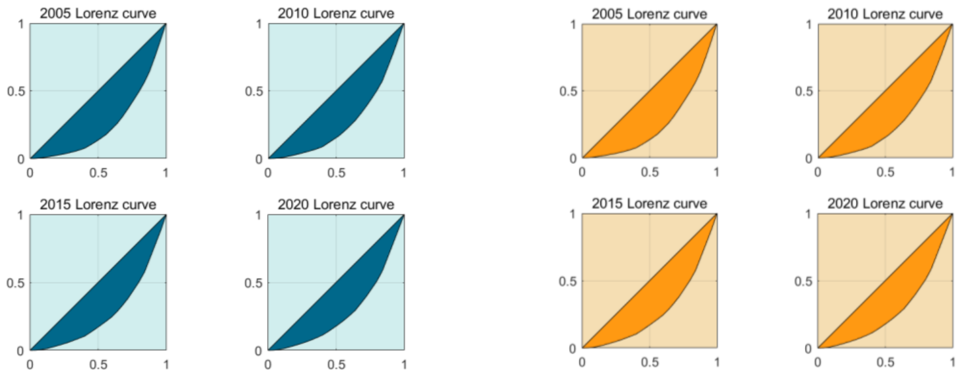


Figure 1: The hierarchical structure of an evaluation model

2.4. Application and verification of the model

2.4.1. Application of the Model

(1) Gini coefficient was taken from the data of the World Bank from 2005 to 2020, with five years as a cycle and divided into four periods. Use MATLAB to draw Lorenz curves of Gini1 and Gini2 (Figure 2) in different periods [11]. And thus the weight coefficients of Gini1 and Gini2 in four years were determined (Table 1).



(a) Lorentz curves of Gini1 *(b) Lorentz curves of Gini2*

Figure 2: Lorentz curves of Gini coefficients

(2) After the above index were standardized, AHP was applied to determine their weights. A comparison matrix *P* was constructed to determine the weight coefficients, and the four indicators in the criterion layer were recorded as C_1, C_2, C_3 and C_4 respectively and compared in pairs. In addition, the consistency was tested with the consistency index (CI) and the consistency ratio (CR) calculated according to Eqs. (3)-(4) respectively, as follows:

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{3}$$

$$CR = \frac{CI}{RI} \tag{4}$$

Where λ_{max} and n represent the maximum eigenvalue and order of the comparison matrix, respectively, and RI represents the average random consistency index corresponding to n. When CR<0.10, the comparison matrix can be considered acceptable; otherwise, the comparison matrix needs to be adjusted and modified.

In the study, the CR value (0.0152) was less than 0.1, that is, the comparison matrix passed the consistency test and was thought to have good consistency, so the weight coefficients calculated by the

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constructed comparison matrix is reliable. Then their normalized feature vector were calculated as the weight vector, and the results are shown in the following Table 1.

Table 1: Results of parameter estimation

	Weights	**2005**	**2010**	**2015**	**2020**
Gini 1	0.2806	0.6010	0.5524	0.5447	0.5494
Gini 2	0.0899	0.4984	0.4754	0.4681	0.4487
ep	0.1793	0.2100	0.1600	0.1010	0.0860
wii	0.4502	0.3297	0.3453	0.3368	0.3421
suM(GI)		**0.3995**	**0.3819**	**0.3646**	**0.3639**

(3) In order to further test the rationality of the factor weight distribution of the model, different judgment matrixes were established through diversified evaluation methods, and the consistency test was carried out. The generated sum of different coefficients and proportions of the above four indexes were obtained, and the data were collected into a formula, and the following column diagram was obtained:

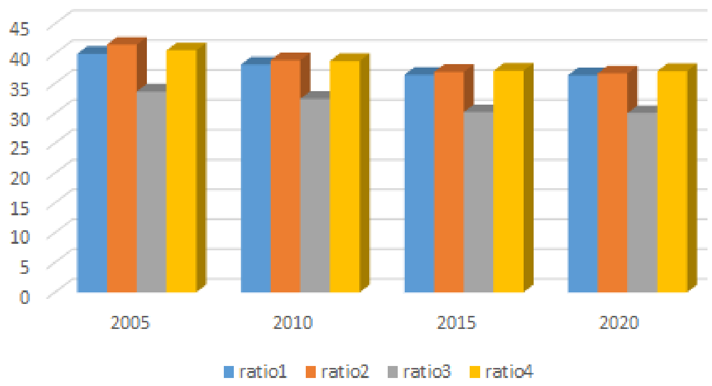

Figure 3: Analysis of weight distribution

It can be seen from Figure 3 that there are some differences in the results under different scale factors, but for each group of scale factors, GI is decreasing year by year, which means that the world is developing towards a more peaceful direction, which is not only in line with the real world, but also in line with our expectations. Under the condition that the four groups of proportional coefficients can meet the preliminary requirements, observe their consistency index CR. The CR of the first group is much smaller than that of other groups, which indicates that the consistency of the ratio coefficient of this group is better than that of other groups, thus verifying the correctness of the selection.

2.4.2. Model validation

Through the above application and solution, it is not difficult to find that the SUM value has shown a downward trend in recent 20 years, which is in line with the trend of global fairness in contemporary society. In addition, the decline rate of Sum value slows down, which is also in line with the social background of stable global economic growth and effective implementation of various policies. To sum up, the establishment of this model is successful.

3. Mining and investment income allocation model

3.1. Overall mining process

The main processes of asteroid mining are transportation, mining and smelting. The order of mining and smelting cannot be reversed, and the transportation process may exist before smelting or mining. Since most smelting needs oxygen, it can only be carried out on the earth. If only considering that the mining difficulty increases with the increase of the distance between the mining site and the earth, the best situation is to transport the mineral resources on asteroids to the surface of the earth for mining. However, considering the friction between the earth's atmosphere and asteroids, the loss of resources and the protection of the earth's environment, it is impossible to transport the mineral resources of asteroids directly to the earth's surface, so we have to rely on the moon for transit. Therefore, the reasonable mining process is defined as: exploring the overall orbital change of asteroids-capturing asteroids by the moon-mining on the moon-building space elevator transportation between the earth and the moon-smelting minerals on the earth.

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3.2. Some of the details for mining

In order to save fuel, the landing date of the asteroid should be chosen on the day of the total lunar eclipse, when the relative velocity between the asteroid and the moon is the smallest. Landing point is the closest point on the moon to the earth, which is convenient for the transportation between the earth and the moon. Asteroid deceleration only changes the speed, not the direction of speed, making its perigee close to the earth orbit more fuel-efficient. The mining process of asteroid mineral resources is shown in Figure 4.

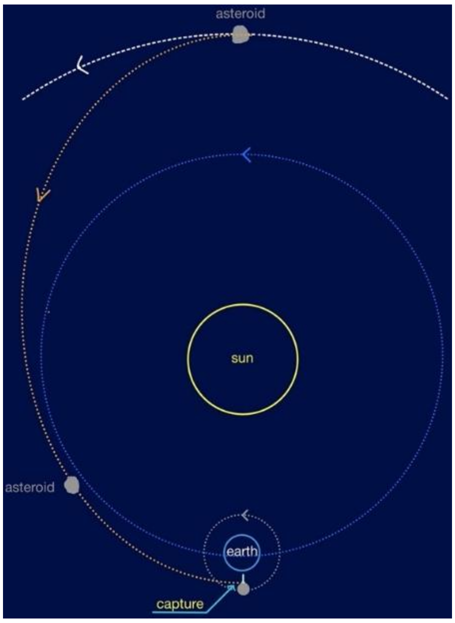

Figure 4: The mining process of asteroid mineral resources

In addition, the space elevator should be accelerated by electromagnetic accelerator before reaching the Lagrange point of the earth and moon, and then it will decelerate to convert potential energy into electric energy. The elevator in space is fixed on the moon, not the surface of the earth. Compared with soil-fixed chain, this scheme can save the number of space elevators and facilitate the transportation of materials.

3.3. Investment income of mining

In the initial stage of mining industry, key technologies are in the hands of a few countries. However, since mining mechanisms and ports are located near the equator, this will lead to cooperation between developed countries and equatorial countries. Therefore, most of the profits will flow to developed countries, a few to equatorial countries, and some to other countries through international organizations. With the development of science and technology, capital participation gradually advances from the downstream to the upstream of the mining industry, which will optimize the structure of the mining industry. According to the experience of globalization, this process will increase the profits of each country and make the profits reach a relatively balanced state. When the mining technology is stable, the whole industry will be largely private, just like today's mining industry, and the profits will be distributed evenly.

3.4. Possible impacts

The development of asteroid mining industry has a certain effect on reducing the number of extremely poor people in equatorial countries, but the effect is limited. How to maximize the beneficial effects of asteroid mining can be considered from the following three aspects.

(1) the influence of war. In order to pursue national interests and control the export of rare minerals, some big countries may launch small-scale wars. If the allocation situation does not meet the ambitions of emerging powers, even a large-scale war will break out. Therefore, the allocation and attribution of minerals are extremely important.

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(2) Technology monopoly. Means the benefits of technological space mining. How to protect the legitimate rights and interests of developers and ensure that technologically underdeveloped countries keep up with the pace is of great significance to global fairness. This can be seen from the gap between the rich and the poor.

(3) Environmental impact: As a large-scale secondary industry, the increase of carbon emissions will inevitably bring huge energy consumption, and how to distribute this part of carbon emissions will affect environmental equity.

4. Conclusion and evaluation

By determining the indicators to measure global equity, a global equity evaluation model was developed by combining with AHP, and an asteroid mining and investment in-come model was established by referring to the existing space technology and science fiction technology. In addition, several aspects of maximizing the beneficial effects of asteroid mining were considered.

This study has some advantages: the established global equity evaluation model can make a more accurate judgment on the whole equity issue from limited information. The model completes dimensionless treatment of all influencing factors, clearly reflects the ad-vantages and disadvantages of each factor, and is convenient to find the main reasons for the lack of global equity in the follow-up work. The technology envisaged in the asteroid mining and investment income allocation model is predictable, conforms to the principle of human science and technology development, and meets the possibility of future mining industry to a certain extent.

However, this study still has such limitations: the global equity evaluation model based on AHP is subjective. AHP is subjective in determining the weights of indicators affecting global equity. Although these weights are accurate at present, they cannot be guaranteed to be accurate with the passage of time. Therefore, in the future work, in order to improve the accuracy of the global equity evaluation model, it is important to expand the influencing indicators and use more objective and realistic weight determination methods.

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