How Asteroid Mining Affects Global Equity

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Abstract. The shortage of mineral resources on Earth is worsening. As a promising form of resource extraction, asteroid mining has technical problems and faces capital challenges. The arrival of asteroid mining is a crucial opportunity to improve global equity. The development of reasonable mining methods and policies can enable asteroid mining to reshape the global economic landscape, which will greatly promote global equity. Firstly, we give a concrete definition of global equity and explain the meaning of the different terms in the definition. Then we quantitatively assess global equity through four dimensions: resources, economy, living conditions, and degree of the rule of law. In order to quantify these four abstract concepts, we introduce a total of 14 different indicators. Then, we design a form of international cooperative mining for the asteroid mining industry in which we build a resource allocation model using national research capacity and research inputs as measures. The model follows the principle of output distribution by input, allowing international companies to extract asteroid minerals, which are then distributed in three ways: company operations, input charity, and shareholder income. Next, we clustered the indicators affecting this international mining company and finalized three conditions. We use these as indicators of changes in the conditions affecting the company. Finally, we discuss the difficulties faced in asteroid mining and the policies that should be implemented based on the results obtained.

Keywords: TOPSIS Analysis; RSR Analysis; Global Equity; Vision; Asteroid Mining.

1. Introduction

1.1 Problem Background

With the development of science and technology, the development and utilization of space resources is now the new frontier of competition between major powers[1]. Among the many planets, asteroids preserve a large amount of valuable information about the formation of the solar system and have a high research value, and the low cost also makes a large number of researchers or companies put their eyes on asteroids mining. At the same time, the issue of international characterization of asteroids and their natural resources has arisen. With the signing of the United Nations Outer Space Treaty, there has been greater concern about global equity in the distribution of resources and other related issues[2]. At the same time, countries around the world should follow the international situation and conduct strategic planning for asteroid resource development.

1.2 Restatement of the Problem

Considering the background information and restricted conditions identified in the problem statement, we need to solve the following problems:

Establish a definition for global equity and build a model to measure global equity and validate it rationally.

Envision a possible vision of asteroid mining and analyze the impact of mining on global equity using the global equity model described above.

Design a model for the impact of changing asteroid mining conditions on world equity under the set vision and analyze it.

Propose incentives for developing an asteroid mining industry and suggest improvements to existing relevant treaties

1.3 Our Work

The topic requires us to explore the impact of asteroid mining on global equity and make policy recommendations based on the results. Our work mainly includes the following:

We define global equity based on our analysis of historical equity initiatives and requirements and develop a model of inequity by the degree of variation in selected indicators across the world.

We create a global corporate system for asteroid mining, draft laws and regulations for the relationship between private asteroid companies and global corporations, and assess the impact on inequity coefficients through the distribution of benefits in the asteroid mining industry.

We develop a model that predicts the future opportunities and challenges for the asteroid mining industry through analogy and historical analysis.

Based on the results obtained from the data processing, we analyze the impact of the introduction of the asteroid mining industry and provide suggestions to design incentive policies according to the degree of privatization.

2. Model I: Global Equity Model

2.1 Defining Global Equity

Global equity means a world relationship in which race, gender, and living conditions are equal, resources are distributed appropriately, information is shared, economies cooperate, mutual support is provided, the rule of law is well established, societies are safe, and there is harmonious coexistence.

2.1.1 Gender equality

In the development of the globalization boom, gender equality is an important issue. The World Bank's World Development Report 2012 defines gender equality as a development objective in its own right. Meanwhile, globalization facilitates the achievement of gender equality in the development process[4].

2.1.2 Racial equality

It means the elimination of racial prejudice and racial discrimination as far as possible, and the existence of equality means the right to enjoy equal opportunities. Racial equality means that although there are physical and customary differences among people of different colors on Earth, there is no distinction between superiority and inferiority.

2.1.3Rational allocation of resources

From the knowledge of economics, it is known that resources in a narrow sense refer to natural resources; resources in a broad sense refer to economic resources or elements of production, including natural resources, labor, capital, etc. It can be said that resources refer to the sum of human, material, and financial resources in social and economic activities, which are the basic material conditions for social and economic development[4]. Resource allocation means that the scarcity of resources determines that any society must reasonably allocate the limited resources to various fields of society in a certain way to achieve the best use of resources, that is, to produce the most applicable goods and labor services with the least consumption of resources and obtain the best benefits[4].

2.1.4 Information sharing

Information sharing refers to exchanging information and information products among information systems at different levels and in different sectors[8]. It allows for a more rational allocation of resources, saving social costs and creating more wealth. Based on mutual respect, all countries should strengthen communication, deepen dialogue and cooperation, and jointly build a community of destiny in cyberspace that is peaceful, secure, open, cooperative, and orderly[6][10].

2.1.5 Economic cooperation

For common interests, different countries in the world carry out a rational reallocation of production factors. All countries should maintain an open, fair, and non-discriminatory business environment[10].

2.1.6 Mutual support

In order to alleviate the inequality caused by the difference in hard power between countries, different countries should help each other and work together to create an international environment of mutual support.

2.1.7 Equitable living conditions

The cost and conditions of food and shelter are the most basic indicators of human living conditions, and the disparity of these conditions among different countries can cause inequality in living conditions

2.2 Detailed Indices

We believe that global equity includes objective conditions and subjective maintenance. Since the factors that shape global equity are too complex, in order to better use this model to quantify global equity and determine the impact of asteroid mining, we decided to set up the model with four dimensions: resource, living conditions, economy, and legal system. For these four dimensions, we use fourteen indicators for numerical quantification, as follows.

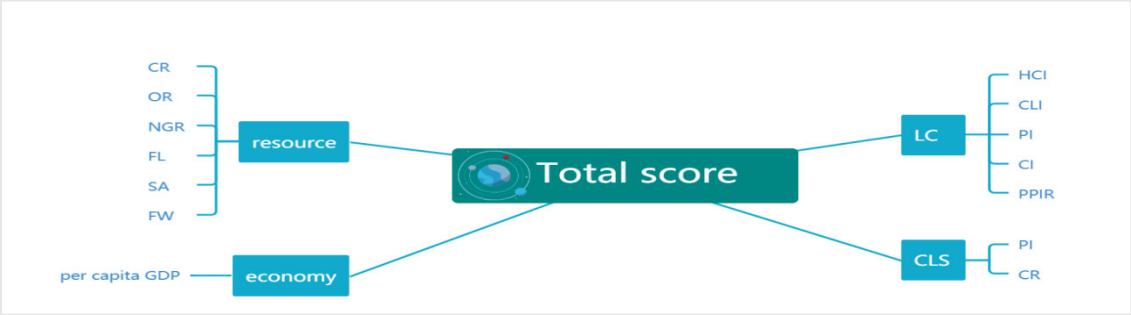


Figure1 The relationship between dimensions and indices

2.2.1 Resource index

Because of the complexity of the Earth's resources, we selected the six resources that have the greatest impact on humanity and used the Topsis analysis to assess the proportion of global resources held by each country. We use each country's reserves of each resource as its possession and create a matrix of each country's possession of each resource:

$$X = \begin{bmatrix} x_{11} & x_{12} & x_{13} & x_{14} & x_{15} & x_{16} \\ x_{21} & x_{22} & x_{23} & x_{24} & x_{25} & x_{26} \\ x_{31} & x_{32} & x_{33} & x_{34} & x_{35} & x_{36} \\ x_{41} & x_{42} & x_{43} & x_{44} & x_{45} & x_{46} \\ x_{51} & x_{52} & x_{53} & x_{54} & x_{55} & x_{56} \end{bmatrix} \tag{1}$$

Also, since different resources have different units, we normalize them uniformly：

$$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} {x_{ij}}^2}} \tag{2}$$

The standardized matrix Z is obtained：

$$Z = \begin{bmatrix} z_{11} & z_{12} & z_{13} & z_{14} & z_{15} & z_{16} \\ z_{21} & z_{22} & z_{23} & z_{24} & z_{25} & z_{26} \\ z_{31} & z_{32} & z_{33} & z_{34} & z_{35} & z_{36} \\ z_{41} & z_{42} & z_{43} & z_{44} & z_{45} & z_{46} \\ z_{51} & z_{52} & z_{53} & z_{54} & z_{55} & z_{56} \end{bmatrix} \tag{3}$$

The matrix is finally analyzed using the topsis principle, where C_i (RI) obtained for each country is the degree of possession of the Earth's resources by each country.

$$D_i^+ = \sqrt{\sum_{j=1}^{m}(Z_{\max j} - Z_{ij})^2} \qquad D_i^- = \sqrt{\sum_{j=1}^{m}(Z_{\min j} - Z_{ij})^2} \tag{4}$$

$$C_i = D_i^- / (D_i^+ + D_i^-) \tag{5}$$

where $Z_{\min j}$ represents the max value of the j-th index, C_i^+ represents total score of a nation's higher education system.

Then, the resource inequality index (INE) between countries is obtained by calculating the variance for all occupation degrees.

$$INE = \frac{1}{N}\sum_{i=1}^{N}(C_i - \mu)^2 \tag{6}$$

Where μ represent the average number of C_i (i=1~6)

2.2.2 Economy index

Since it is difficult to quantify the overall GDP due to the large population differences of each country, we use the GDP per capita of every country as a quantitative indicator of each country's economic capacity. We believe that the higher the GDP per capita index of a country, the higher the economic capacity. Since this index is treated the same way as the previous one, we will not repeat it.

2.2.3 Living condition index

The difference in the living environment due to factors such as house prices and environmental indices is also a measure of global inequality. These are the health care index, cost of living index, pollution index, climate index, and house price to wage ratio. We evaluated these indices by Topsis to obtain the survival indices for each country. We then calculate the variance (INE) of each country's Survival Index to obtain the Survival Inequality Index between countries.

2.2.4 Coefficients of legal system index

The degree of lawlessness is different from the objective indicators above. Using the proportion of the population of the selected countries (PPS) in the total population as weights, we linearly weight each country's crime rate (CR). The final index (CLS) is obtained as the lawlessness coefficient in the selected, overall environment, representing the degree of lawlessness. The calculation formula is as follows:

$$CLS = \sum_{i=1}^{6} PPS \times CR \tag{7}$$

3. Model and Measurements

3.1 Model building

We define the degree of inequality:

$$INE = 100 \times CLS \times (LC + RES + ECO) \tag{8}$$

where resources, economy, and living conditions are objective indicators that represent the gap of hard power between different countries, and the sum of each coefficient represents the degree of inequality. The coefficient of the rule of law represents the subjective degree of the people's defense of the principle of equity and related laws.

3.2 Model measurements

The absolute fairness is reached when and only when the crime rate of each country is 0, and the variance of all objective indicators is 0, so the ideal absolute fairness condition of the inequality index is 0; when the crime rate of each country takes the maximum of 1, the wrongdoing coefficient is 1.

The maximum value of this index is 75 from mathematical analysis, but it cannot be reached in practice. So we chose three developed countries and three developing countries and calculated their inequality to be 24. Similarly, we obtain inequality measurement by calculating inequality for multiple groups of countries, as follows:

Table1 Comparison of the degree of fairness and inequity

Degree of fairness	Inequity
Very fair	0~3
Relatively fair	3~8
Relatively unfair	8~15
Very unfair	15~25

3.3 Model Verification and Analysis

Here we use the data of six countries, including the United States, Canada, the United Kingdom, Russia, China, and Japan, and we can obtain the inequity degree of 4.86 in this environment, which is within the model measurement range (3 to 8). By analyzing the objective facts of these countries, we can tentatively conclude that the model can reflect the degree of fairness among different countries.

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4. Model II: Impact of Asteroid Mining on Global Equity

4.1 Mining Vision Description

Our vision is to establish an international mining company with both commercial and public benefits in a global cooperative manner. Equity would then be allocated in the company based on the financial and technical inputs of countries worldwide, with the following institutional requirements and statements.

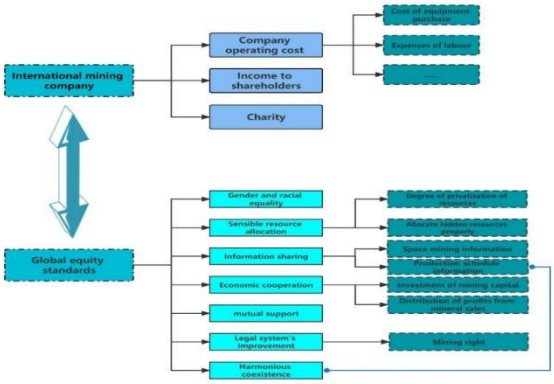


Figure2 Our Vision of Asteroid Mining

By the criteria in global equity, any country in the world has the right to mine, i.e., the mining company receives any financial input and scientific and technical personnel, etc. Each country may hire research experts to provide the mining company with advanced and viable mining and transportation technologies or provide research results such as patents on mining machinery in exchange for equity. The equity share in the initial establishment will be divided according to the number of funds contributed by each country and the scientific and personnel input.

By information sharing standards, information on the space minerals explored by the company and mining progress is available to the world.

Following the rational distribution of resources, the company is considered a way for the people of the world to exploit space minerals and does not possess any space mineral resources, all of which belong to the world.

In accordance with the principle of harmonious coexistence, the company does not hold and opposes all armed forces in space.

In accordance with the criteria of rational distribution of resources, the company recognizes all existing and adopted public laws for private mining of asteroids and admits the statements of the persons concerned. However, any private company wishing to acquire a private interest in space minerals for national or personal use must pay a mining income tax to the Corporation. Furthermore, the company determines the maximum amount of mining allowed per year per company, and if the limit is exceeded, a corresponding overflow tax is required.

By applying the criteria of rational allocation of resources, each country receives the benefit of the resource itself and has the right to invest human capital and technology in the company to obtain shares. The company shall not take possession of any mineral resources. However, the resources are distributed by the mining company, i.e., more for more work, less for less work, and reasonable distribution.

Regarding the flow of profits, the first part of the company's profits will go to the company as operating costs, including the purchase of related equipment, staff salaries, etc. The second part will be the central part, which each shareholder will receive. The third part will be donated to charity for the mutual development of people worldwide, based on the global fairness index of mutual support.

4.2 Using RSR-like Algorithm to Build Equity Allocation Model

In order to determine the share of each country in the international mining company, we calculate the rank and ratio of each country's research capital investment and existing research capacity. We obtain the RSR index (which represents the research strength of the country) and use it as the share that each country can acquire in the international mining company. The formulas are as follow:

$$R = \begin{bmatrix} R_{11} & \cdots & R_{1m} \\ \vdots & \ddots & \vdots \\ R_{n1} & \cdots & R_{nm} \end{bmatrix} \tag{9}$$

$$RSR_i = \frac{1}{m \cdot n} \sum_{j=1}^{m} R_{ij} \tag{10}$$

Where R_{ij} represents The rank of the element in the j-th column of the i-th row

$$WRSR_i = \frac{1}{n} \sum_{j=1}^{m} \omega_j R_{ij} \tag{11}$$

Where ω_j represents the Weight of the j-th evaluation indicator.

Since there is no precedent for investment in space mining, we assume that the amount of capital invested by each country in the establishment of the company is measured as a purely scientific project investment. The amount of funding (symbol) is obtained by multiplying the number of researchers and the research funding per researcher. Here we take the approximation of research funding by each country in 2021 as the funding to the IMC.

For the research capacity, we take the number of scientific papers published in the country, the number of citations of scientific papers, and the number of existing researchers, and then we evaluate them by topsis to get the research capacity index of the country. We believe that the higher the research capacity index, the higher the country's investment in research technology.

5. Conclusion

To determine the impact of asteroid mining on world equity, we selected two representative countries that are more likely to be involved in the space mining business in the Americas, Europe,

and Asia. The United States, Canada, Russia, the United Kingdom, China, and Japan. For example, asteroid 241, with a market value of $95.8 trillion, was chosen to determine the impact of asteroid mining on world equity by calculating the change in global inequity before and after mining by countries in the form of international mining company allocations.

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