Research on the fairness of asteroid mining based on Country-Equity Coupling algorithm

Haotian Pan*, Yanqi Li, Haozhe Pan

Beijing University of Chemical Technology, Beijing, 100029

*Corresponding author: panhaotian0305@163.com

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Abstract: With the rapid development of advanced space technology, asteroid mining has aroused growing attention worldwide. The potential harm of irrational allocation of space resources threatens every country globally, especially those with weak comprehensive national strength. A fragile country cannot defend its fundamental interests in space and is vulnerable to an irrational allocation of space resources. As a result, how to measure the fairness of asteroid mining, to develop a model to measure the fairness appears imminent. Our Country-Equity Coupling (CEC) Model provides a quantitative analysis of equity degrees for most countries in the world. It considers multiple aspects, including history, humanities, region, politics, economics, etc. First, after extensive research, we came up with five creative principles to measure equity in the world. At the same time, we select relevant indicators for each principle and propose formulas to quantify them. Since it is challenging to assign weight to each index according to experience, we propose a deprivation coefficient to measure the perception of distributive justice. With deprivation coefficients and indicators, it is not hard to build a model of world equity. Second, we imagined the future of asteroid mining. We think asteroid mining will have a wide range of applications in the future, most notably in the construction and repair of satellites. Based on the TOPSIS model, we designed relevant algorithms and finally visualized the impact of mining on global equity on a world map. Third, we extracted and quantified the two elements that considerably impact production and revenue, respectively. When comparing the weights of the elements with different values, we found that the results did not change significantly. The difference between the maximum and minimum values is only 16%

1. Introduction

It is always cool to see people around the wearing accessories made of space minerals. Asteroid mining is coming! Human beings have an endless imagination of space, the resources on the earth are on the verge of depletion, and people's eyes are gradually turning to space [1]. With space technology development, asteroid mining has become a safe and lucrative industry. However, these mining resources are related to the vital interests of all countries in the world now. In the future, according to the treaties signed by various countries (on the principles to be observed in the activities of foreign space exploration and use of outer space, including the moon and other celestial bodies) [2, 3], any outer space asteroid does not belong to the territory of a sovereign country, in the case of a huge difference in national strength and scientific and technological level, the expansion of the ambitions of large countries and small countries in the gap to seek survival in the situation is in stark contrast. How to equitably allocate space mining resources has become an urgent problem to be solved. We will build a model to explore the impact of mining on world equity. However, we encounter the following problems: 1) The amount of storage ore and storage value of the planets is uncertain. 2) How to collect planetary mineral deposits. 3) Distributing the collected mineral deposits to make the world fair. Therefore, a solution to the space mining problem is imminent.

2. Method

2.1. Global Equity Indicators

We define world equity because each country has a corresponding share of space resources that enables its economy to develop rapidly. At the same time, world fairness is not absolute but relative. Through extensive access to the material, we abstracted the following five principles (the P_5 Principles) [4, 5] to measure world equity:

•The principle of economic capacity. Economic capacity is also often referred to as the principle of ability to pay, and in general, the social governance structure requires groups with the higher economic ability to bear higher costs for product supply. In the process of asteroid mining, countries and regions with higher levels of economic development should have greater responsibilities, and using the Gross Domestic Product (GDP) indicator to measure the responsibilities of countries in world equity is an appropriate option.

•The principle of relative quantity. Although mineral reserves are unlimited, the exploration and use of outer space shall be carried out for the benefit and interests of all States, irrespective of the degree of economic or scientific development. They shall be responsible for the relative quantity of minerals extracted for the purposes of all human beings, following the treaties concluded by States.

•Principles of interpersonal equity. Scholars who insist on interpersonal fairness believe that the pursuit of historical responsibility makes contemporary people responsible for historical people. Jameson, president of the International Society of Environmental Ethics, points out that equal per capita is the most rational distribution principle, which directly allows each person to have as many emission rights as others.

•Grandfather principles. The principle of grandfather hood asserts that every country or economy has equal rights to mine asteroid minerals and that the right to constitute a future share of the past and existing scale of exploitation by each country is justified. Allocating future mining quotas based on recent mining scales, the principle of grandfatherhood reflects respect for the countries' desire for more resources. The greatest advantage of the grandfathering principle is that it reduces the resistance to the distribution of mining shares.

•The principle of cosmic order. This principle requires the limits of anthropocentrism to be removed, which comes from the limitations of the universe as a whole. Moreover, the allocation of mining quotas should maximize the value of the system. Asteroid mining is only a small part of the value of the entire universe. The vast universe still has many unsolved mysteries waiting for us to solve, the immeasurable treasure waiting for us to discover. Our vision cannot be limited to this corner.

2.2. Country-Equity Coupling Model (CEC)

Starting from the four dimensions of ability, fairness, responsibility, and feasibility, we explore the impact of various factors on world fairness under the guidance of the corresponding principles of each dimension.

Table 1. Allocation Principle and Estimation Formula

dimensions	Allocation principles	Estimation formula
ability	Equal output	$Q_i^1 = Q_w \cdot \frac{gdp_i}{\sum gdp_i}$
fair	Interpersonal equity	$Q_i^3 = Q_w \cdot \frac{pop_i}{\sum pop_i}$
liability	Production responsibility	$Q_i^5 = Q_w \frac{pop_i}{\sum pop_i} + \lambda_w^{hpe} \cdot \sum pop_i^{ht} - \sum out\_q_i^{ht}$
viability	Grandfather system	$Q_i^2 = Q_w \cdot \frac{(q_i^{t-5} + ... + q_i^{t-1})}{\sum q_w^{t-5} + ... + q_w^{t-1}}$
	Cosmic systems	$Q_i^4 = Q_w \cdot \frac{la_i}{\sum la_i}$
	Consumer Responsibility	$Q_i^6 = Q_w \cdot \frac{pop_i}{\sum pop_i} + \lambda_w^{hpe} \cdot \sum pop_I^{ht} - \sum cos\_q_i^{ht}$

The estimation formula of the three principles of equal output, interpersonal fairness, and the cosmic system is easy to understand, and here we use several charts to visualize the proportion of countries.

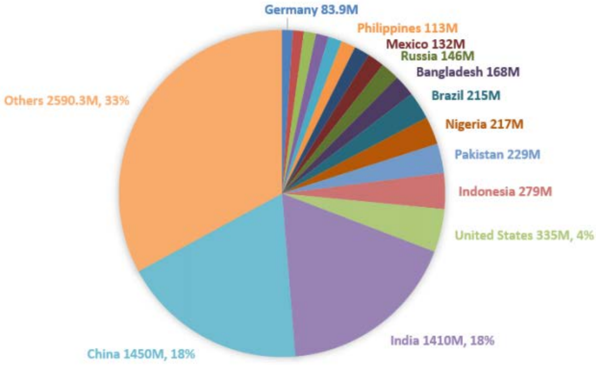

Figure 1 Global Population

2.3. Deprivation Coefficient

In order to better balance the differences in political, economic, cultural, and other backgrounds in various regions, we introduce the concept of deprivation coefficient and carry out weight design and weighted quota estimation based on deprivation coefficient.

According to Runciman's definition of relative deprivation, Yizhaki proposed a method for calculating the relative deprivation coefficient. Group X is supposed to be X = (x1, x2, ..., xm), and m is the number of samples. x_r and x_s are from group X. Individuals r and s in the group. As long as it exists $x_s < x_r$, individual s will give birth to generate a sense of relative deprivation. If there is a total of n_+ for individuals greater than x_s in the group X. They account for a proportion of λ_+ in the X colony, and these are greater than the mean of x_s individuals for $\overline{x}_+$, the average sample of the X swarm is $\overline{x}$, and x_s is the normalized phase for the X swarm The formula for calculating the deprivation coefficient is:

$$d(x,x_s)=\sum_{i=1}^{m}\frac{d_X(x_r,x_x)}{m\overline{x}}=\frac{(n_+\times\overline{x}_+-n_+\times x_s)}{m\overline{x}}=\frac{\lambda_+(\overline{x}_+-x_s)}{\overline{x}} \tag{1}$$

According to the relative deprivation coefficient estimation, the relative deprivation coefficient of the region under a particular principle is large, the sense of deprivation distributed under this principle is high, and the degree of fairness is low. In order to improve the sense of fairness of distribution, the weight that should be given to this principle is small, and vice versa. The weight of the comprehensive weighted distribution based on fairness should be inversely related to the deprivation coefficient, so the weight allocation function is constructed. p_k represents the weight corresponding to the k principle. This article uses common probability functions, and the weight allocation function is:

$$p=f(\delta)=\frac{1}{1+e^{\delta}} \tag{2}$$

$$p_k=\frac{f(\delta)}{\sum_{k=1}^{5}f(\delta)} \tag{3}$$

According to formula (3), we calculate the weights of the evaluation system occupied by the principle of economic ability, the principle of relative quantity, the principle of interpersonal fairness, the principle of grandfathers, and the principle of cosmic order.

Table 2. Allocation Principle and Estimation Formula

Allocation principles	Relative deprivation coefficient δ_k	weight
Equal output	0.22	0.2
Interpersonal equity	0.3	0.1
Production responsibility	0.2	0.28
Grandfather system	0.05	0.07
Cosmic systems	0.05	0.13
Consumer Responsibility	0.18	0.12

2.4. TOPSIS impact velocity algorithm

The establishment of a normalization matrix, the standardization of data:

$$Z_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n} X_{ij}^2}} (i = 1,...,m; j = 1,..,n) \quad (4)$$

Where *i* represents the number of cells selected or constructed, *j* represents the number of indicator systems constructed, X_{ij} table shows the score of the j_{th} evaluation index system in the i_{th} cell. (Data normalization can also be implemented through SPSS: open database- > analyze- > describe- > statistics- > standardize data).

From the Z matrix obtained above, the optimal vector Z_j^+ = max|Z_{ij}| and the worst vector Z_j^+ = min|Z_{ij}| is obtained (i⊂ [1, m]).

Calculates the euclidean distance of the indicator to the optimal vector $D^+ = \sqrt{\sum_{j=1}^{n} (Z_{ij} - Z_j^+)^2}$ and the worst vector $D^+ = \sqrt{\sum_{j=1}^{n} (Z_{ij} - Z_j^-)^2}$ for each cell selected or constructed;

Finally, the relative proximity to the optimal value $W_i = \frac{D_i^-}{D_i^+ + D_i^-}$ is obtained.

The main process of TOPSIS [6] is as follows:

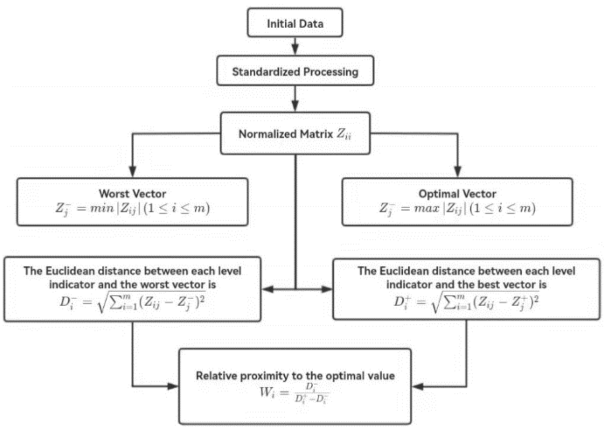

Figure 2 TOPSIS Process

3. Results and discussion

3.1. Effect of the intermediate constant an in the weighted mean

We set a to 0.15, and it never changes again when using the weighted average method to give the weight of each indicator. We calculate it based on the national vulnerability index of developing countries, choosing a constant of 0.15. Figure 3 is obtained that a's value varies from 0.10 to 0.20 by 0.25. Each curve represents a different value, and all show the same trend. Therefore, the Self-Regulation of Risk Resistance (SR) model is not sensitive to the value of the intermediate constant a.

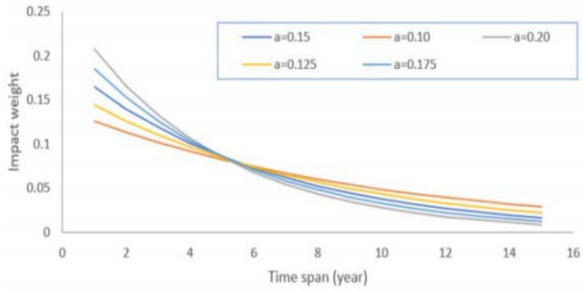

Figure 3 Global Population

3.2. TOPSIS impact velocity results

We used the TOPSIS model and designed the corresponding algorithm program to evaluate the relative equity of each country. After ranking, the results are shown in Figure 4. From green to red, the darker the color, the greater the share allocated to the country or region.

Figure 4 Global distribution

3.3. Prospects for Asteroid Mining and Key Influencing Factors

(1). Satellite Part

Based on the survey, the transformation of sputnik will account for a large part of the profits from the exploitation of asteroid deposits. The number of sputniks to be modified S consists of newly launched satellite A, in-service satellite depreciation, and satellite retirement B. The data shows that the number of newly launched satellites each year increases linearly, while the number of retired satellites remains unchanged, so after introducing the launch growth coefficient η_1 and depreciation coefficient η_2.

The dynamics of satellite population can be shown as:

$$\frac{dS}{dt} = \eta_2 (S + \eta_1 A - B) \tag{5}$$

(2). Ore Production Part

Similar to the first part, ore production W depends on the relevant enterprises and institutions established in each country, the number of mining machines M, the relevant staff C. In our hypothesis, minerals are unlimited, and asteroid mining is always profitable, so changes in businesses and institutions should also level off. With the development of science and technology, the development of mining machines should maintain rapid growth, and due to the harsh environment in outer space, maintenance personnel should tend to a stable value. So, after the introduction of the enterprise growth coefficient λ_1 and the mining machine growth coefficient λ_2. The dynamics of production can be shown as:

$$\frac{dW}{dt} = \lambda_1 (T + W + \lambda_2 M) + C \tag{6}$$

The calculation result is as follows:

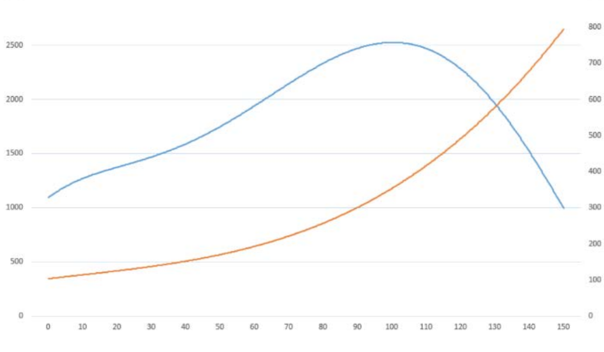

Figure 5 Mineral production and satellites to be fixed with specialization.

As ω_1 and ω_2 change, qi changes roughly:

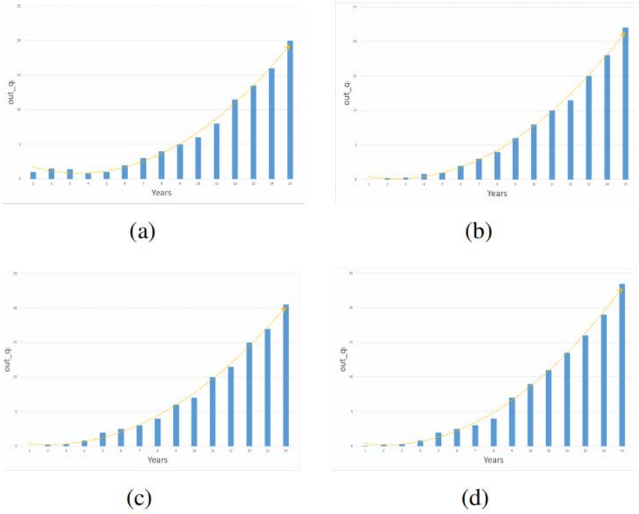

Figure 6 Out_qi expectation curves.

We chose 4 typical values for w: (a) ω_1 = 0.2, ω_2 = 0.8, (b) ω_1 = 0.4, ω_2 = 0.6, (c) ω_1 = 0.6, ω_2 = 0.4, (d) ω_1 = 0.8, ω_2 = 0.2 to get out_qi expectations. The difference between the values of different w is not significant, and the difference between the maximum and minimum values is only 16%.

4. Conclusion

In order to promote more measures to move forward in a globally equal way, according to the above analysis results, more than 50 years of space exploration has helped us to gradually deepen the understanding of space resource exploration such as asteroid mining. The following conclusions are obtained:

First of all, to accurately define equity, we established a coupled model named CEC based on state and equity, which can reflect the equity strength. This model also quantifies other important indicators of history, location, and economy.

Second, we are required to establish a model to determine the impact of mining on global equity. Then we are expected to imagine the future of asteroid mining. In addition, we have to consider the impact of different conditions on our model, such as Ore production and satellite amount, etc.

Finally, in order to provide policies for the asteroid mining sector and to encourage it to promote the development of countries around the world in an equal manner, we apply the entropy weight method to integrate the CEC model and results previously available in part into the model for assessing national vulnerability indicators. Moreover, it applies the latest-determine and average weighted methods to do data weighting for different indicators. The self-regulation of Risk Resistance index model SR was further constructed to find the relationship between self-regulation factors and risk event probability in the mining process, and it was tested with the example of the actual country (USA). To determine the relative fairness of each country's entitlement and thus accurately provide policy recommendations to rationalize the asteroid mining sector and ensure that it benefits all mankind, in line with the concept of a community with a shared future for mankind.

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