

Allocation Issue of Asteroid Mining: A Symbolization of Global Equity

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Abstract. Nowadays with the advance of the space exploration and the large-scale utilization of mineral resources, many nations begin to put their eyes on 'Asteroid Mining'. In fact, the United Nations' Outer Space Treaty was signed 55 years ago. But with new problems about global equity and interest protection popping up, it's quite essential to update the original treaty. In order to structure a solid fundamental for our analysis, we firstly build a definition model to define the 'Global Equity'. We use great amount of indicators searched from OECD and integrate them into four main factors: 'Resource', 'Society', 'Economy' and 'History'. Through 'AHP' and 'TOPSIS', we work out the weights of every factor and their sub-indicators. We successfully build the Equity Assessment Model (EI model) and the importance of each factor appears immediately. Then we calculate the EI value of each nation which shows the overall condition of the nation in the course of resources allocation. Based on the data we get, we classify the nations into three grades: 'Top Qualified Countries', 'Rest Qualified Countries', 'Unqualified Countries'. The explanation will be given later. So how are the mineral sources allocated in the market? We think the mining countries should get rewards to cover the cost of researching and exploring. Also, the 'Unqualified Countries' should be aided and given some welfare and discount. The rest countries purchase their share of minerals regularly. Different countries have different shares of mineral resources they can purchase based on the Allocation Model we build. We use the Regression Analysis of input-output and Copulglas function to help build the model. The share scheme and welfare scheme are two features of our analysis. After that, we jump to the conclusion that the economy and even the whole world will get better after the asteroid mining is implemented.

Keywords: Institution, Allocation Model, share scheme, welfare, classification.

1. Introduction

Multiple countries signed onto the United Nations' Outer Space Treaty of 1967 about the right and aim to explore and exploit the source of outer space. Asteroid mining brings about several problems including the uncertain feasibility in terms of technology and financing condition. [1-2] The role of government and private companies should also be taken into consideration when it comes to capital raising. Besides, how to guarantee equity is of the greatest importance thus making a reasonable policy the matter that worth pondering.

In this paper, first we define the definition of equity. Then we considerate a large number of OCED indexes as EI indexes. We screened out the fairness evaluation model indexes. Combining with AHP-TOPSIS analysis, we get the index weight and equity assessment model. After that, We imagine the future of asteroid mining. Then we take data from forty countries, calculate their values, and divide them into three categories. On the basis of the first model and country classification, we develop the allocation model. It is divided into two parts, one is share scheme and the other one is welfare scheme. It turns out that we not only guarantee the allocation equity between several nations but also give reward to the contribution of 'Top Qualified Countries' and support the 'Unqualified Countries', which greatly improves the development of economy and technology all over the world.

2. Equity Defining and Assessment Model

What is the global equity? Based on Rawls principle, our team believes that global equity means that all countries, groups or individuals enjoy equal rights to development, especially how to promote and improve the welfare of the most vulnerable groups in society[3]. Global equity manifests itself in different ways in different situations. So the way to measure it is to establish an organizational structure that combines different disciplines. A fair global environment means allocating resources reasonably to all countries or groups in the world and giving assistance to vulnerable groups, so as to achieve the goal of obtaining what each needs and developing together. [4-5]To this end, we believe that a sound and fair evaluation system needs to consider four main factors simultaneously: Resource, Society, Economy and History. To comprehensively measure global equity, we present the following evaluation model.

2.1 Indicators

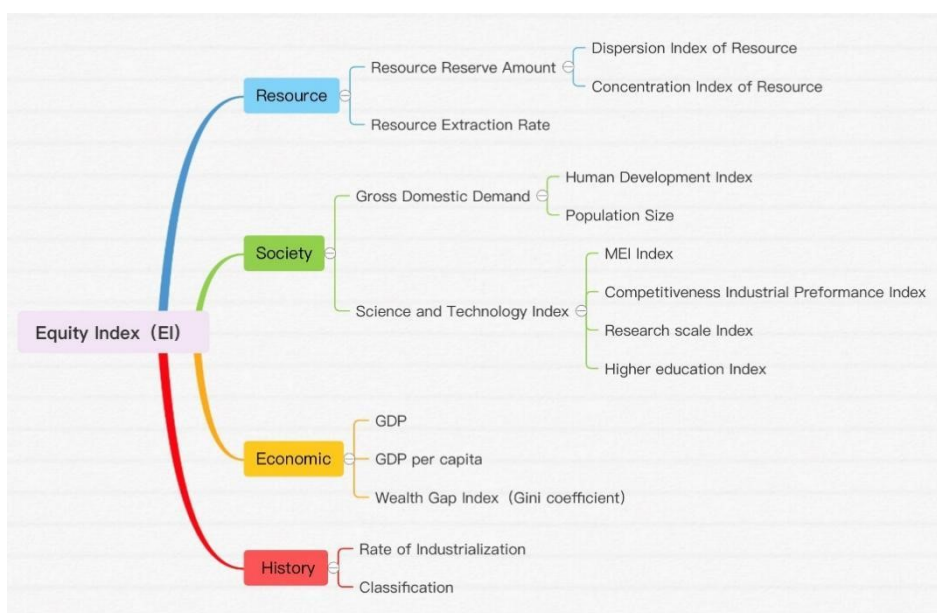


Figure 1: tree diagram of Indicators

- Resources

‘Resources’ measures the richness of mineral resources owned by a specific nation. Two secondary indicators of it: ‘Resource Reserve Amount’ and ‘Resource Extraction Rate’ respectively measure the overall condition of the nation’s natural environment and resource utilization rate of the nation.

- Society

‘Society’ contains gross domestic demand and science and technology index. Gross domestic demand will be qualified through HDI[6] and population. And science and technology index has four secondary indexes. These data is from OECD. We use the number of patents belonged to country (RSI). It measures the scientific level of the country. And we also use the ratio of college students to the total population(HEI). It measures the potential of science and technology development of the country.

- Economy

‘Economy’ indicates the level of economic development of the country. This indicator will be divided as three secondary indicators: GDP, GDP per capita and wealth gap index(Gini coefficient[7]).

- History

‘History’ emphasizes the impact of poor development resulted by the history. It will be qualified through two indicators: rate of industrialization = $\frac{CPI}{T}$ (T is defined as industrialization time) and classification. The index is used to indicate whether a country develops slowly due to colonization, war and other factors. And classification indicates the class of countries (developed country, developing country, poor countries).

Table 1: Notations used in this paper

Factor	Description	Unit	Data type
GDP	(dollarwise)	Ten thousand	Max
GPC	GDP per capita(dollarwise)	Thousand	Max
WGI	Wealth gap index(Gini coefficient)	-	Min
ISR	Industrial structure rationalization index	-	Max
RI	Rate of industrialization	-	Max
C	Classification(developed country, developing country, poor countries)	-	Max
RRA	Resource reserve amount	%	Max
RER	Resource extraction rate	%	Max
GDD	Gross domestic demand	-	Max
STI	Science and technology index	-	Max
EI	Equity index	-	Max

The ‘max’ means the higher the number is, the better it is. The ‘min’ means the lower the number is, the better it is. When the country is a ‘Top-Qualified Country’, CF is 5. When the country is a less developed country, CF is 3. When the country is a developing country, CF is 1. (Secondary indicators with third-grade indicators are not listed in the

Table 1. We take the average of the tertiary indicator to which a secondary indicator belongs as the value of the secondary indicator in a sample.)

2.2 Determination of the Weight

The chief method to determine the weight is analytic hierarchy process (AHP). It accurately quantifies the weights of various indicators in different decision situations like policy decisions, business analysis, education and so on. We have selected several chief factors in consideration of our mission. We think it essential to split the factor into four parts: ‘Resource’, ‘Society’, ‘Economic’ and ‘History’. The factors’ range is quite crucial to help defining ‘Equity’.

With the help of Pairwise comparison, we reckon the priorities among the factors. The importance of each main factor satisfies the relationship as follows:

$$\text{Economy} \approx \text{Society} \geq \text{Resource} \approx \text{History}$$

We can calculate the eigenvalues and eigenvectors of the matrix before. Next we need to perform consistency test with the maximum eigenvalue λ_{\max} .

$$CI = (\lambda_{\max} - n) / (n - 1) \tag{1}$$

$$CR = CI / RI \tag{2}$$

After passing the consistency test, the weights of main factors by eigenvector corresponding to the maximum eigenvalue: Resource(0.1097), Society(0.38), Economy(0.4083), History(0.1021).

Since we have tackled four main factors and made clear that each factor plays a certain role in the course of policy making, we get to research the importance of the secondary indicators. The method is similar to the previous one and the weight of each is shown in the following figure 2:

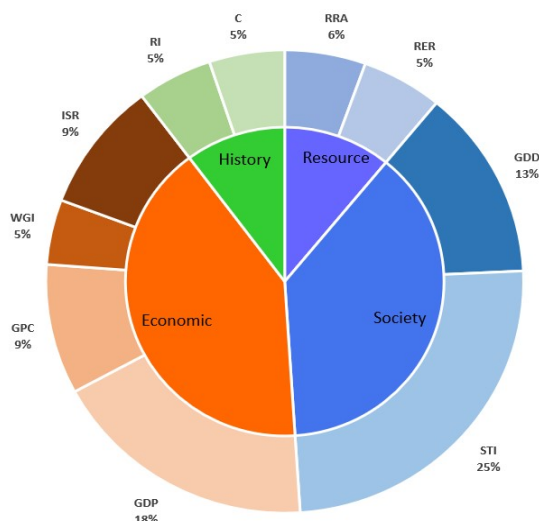


Figure 2: Weight of each indicator

We successfully get the rankings of indicators according to weight analysis. Main factors are those which rank high thus exerting great impact on the countries' condition and equity between nation and nation. They are key indicators concerning the global economic growth as well based on the previous research on economic globalization.[8]

2.3 TOPSIS synthesis

There are two data types in our original data: maximum indicator (GDP) and minimum indicator (GINI coefficient). Topsis requires the former one only so we need to deal with the data type. We use this method to achieve our goals: $y_i = x_{\max} - x_i$. (y_i shows the data that has undergone the forward transition, x_i is the original data, x_{\max} is the maximum data of the original ones) Because the measurement units of the selected index data are different, it is necessary to conduct dimensionless processing on the data after assimilation to make them comparable with each other.

The optimal scheme is the best scheme envisaged, and its corresponding attributes at least reach the best value in each scheme; The worst-case scenario is the putative worst-case scenario, which corresponds to properties that are at least not better than the worst values in each scenario.

The optimal solution Z^+ is composed of the maximum value of each column in Z :

$$Z^+ = (\max Z_{i1}, \max Z_{i2}, \dots, \max Z_{im}) \quad (3)$$

The worst plan Z^- consists of the minimum value of each column in Z :

$$Z^- = (\min Z_{i1}, \min Z_{i2}, \dots, \min Z_{im}) \quad (4)$$

Calculate the distance between Z^+ and D_i^+ and the distance between Z^- and D_i^- for each evaluation object. The calculation of the distance here needs to use the weight calculated by the IEW method in the previous section.

$$D_i^+ = \sqrt{\sum_{j=1}^m w_j (\max z_{ij} - z_{ij})^2} \quad (5)$$

$$D_i^- = \sqrt{\sum_{j=1}^m w_j (\min z_{ij} - z_{ij})^2} \quad (6)$$

E_i is a number within [0,1], indicating the comprehensive power of the nation. We need to calculate the closeness EI between the evaluation object and the optimal solution.

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad 0 \leq C_i \leq 1 \quad (7)$$

3. Future Shaping and Allocation Model Establishment

3.1 Classification of the Countries

Different countries' situations vary greatly in terms of factors including citizens' well-being, wealth, production and so on.[9] We firstly define two concepts of the countries involved in the activity: 'Qualified Country' and 'Unqualified Country' in terms of the ability to complete the mission of asteroid mining imagined that the asteroid mining. To better describe our model, we classify the nations into 3 grades. The first grade(G1) includes the top 'Qualified countries' that have high quality of the scientific research and adequate fund to support the asteroid mining. The second grade(G2) includes the rest 'Qualified countries' that can pay for their shares regularly although they don't have the capacity of exploring the space. The third grade(G3) includes the whole unqualified countries which have difficulties in paying for the expensive mineral resources brought from the outer space. They need relevant resources and aids urgently.

3.2 Allocation Model

After the allocation, we develop the allocation scheme to quantify the distribution process. We divide the mineral into 2 groups, respectively used for the share scheme and investment scheme. Our thought is shown as Fig3:

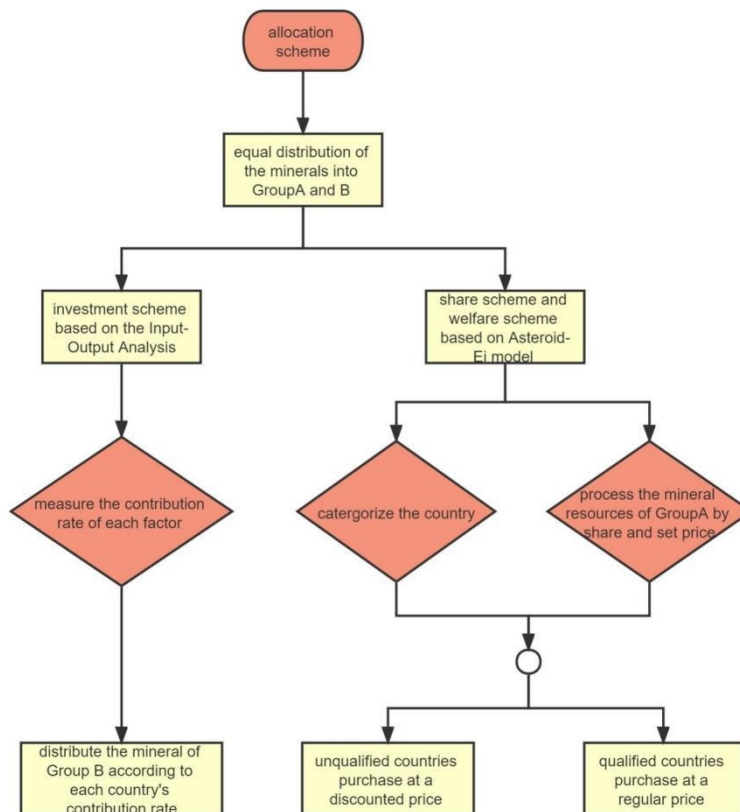


Figure 3: Our workflow of allocation scheme

Before building the Allocation Model, we began to analyze the relationship between resource shares and the condition of nations that we analyze:

$$a_i = \frac{EI_i}{\sum_{n=1}^n EI_i} \quad (8)$$

a_i is the share allocated by each nation. EI_i is the EI index of each nation and it is within $[0,1]$.

Each nation can purchase the mineral resource based on the share they deserve. a_i is the maximum of the purchasing amount.

The second formula we have is a welfare formula as follows:

$$SC_i = d_i * a_i * M_i \tag{9}$$

SC_i is the allocating price. D_i is the welfare index regulated by the institution. M_i is the price.

Our welfare scheme is mainly provided for the ‘Unqualified Countries’. The welfare includes some discount on the price.

Then we begin to build the Input-Output Analysis Model of the asteroid mining model. Based on the model we built, we believe that investment exists in form of talents, funds and technology. We employ the Copulglas function[10] to our model and the function is set as :

$$IC_t = A_t * F_t^\alpha * L_t^\beta * T_t^\gamma \tag{10}$$

A_t is the level of asteroid mining’s efficiency in the t_{th} period. IC_t is the output of asteroid mining. F_t is divided into two parts : the input of the national or private consortium (F_{pt}) and input of the government(F_{gt}). L_t includes the higher talents input(L_{ht}) and ordinary talents input(L_{ot}). T_t is the technology investment in the t_{th} period.

Given that the asteroid mining has not been put into practice, we can’t obtain the following data. We only consider the consideration of the first period($t=0$). Considering that the asteroid mining industry has something in common with the high-tech industry, we use the output of 48 nations’ high tech industry to measure the output of asteroid mining (CI_1). F_{p1} and F_{g1} are calculated respectively with the data of investment of private consortium and national government.(in unit of 10000 dollars). L_{h1} and L_{o1} are the employment rate of high-tech staff and the ratio of labor force. T_1 is science and technology index.

We get the outcome by STATA:

Table 2: The outcome of regression analysis

The Results of LR n=48							
	Normalization coefficient Beta	t	p	VIF	R ²	adjusted R ²	F
C	-	0.387	0.702	-			
Fp0	0.072	0.762	0.454	1.467			F=28.295
Lo0	0.024	0.296	0.77	1.029	0.865	0.835	P=6.9388
Fg0	0.654	6.36	0.001***	1.726			89017994
T0	0.331	3.229	0.004***	1.715			246e-9
Lh0	0.158	1.793	0.037**	1.263			

Dependent Variable: IC0

After F-test, we find the P index is 0.000***. The significance is shown in the horizontal direction, denying the original assumption where the regression coefficient is 0. The model is established well because adjusted R2 =0.835. The LP model after standardization is as follows:

$$\ln IC_0 = 0.654 * \ln Fg_0 + 0.158 \ln Lh_0 + 0.331 * \ln T_0 \tag{11}$$

The model demonstrates that High-Tech talent input, the government’s investment and the level of science and technology are significant factors and have great impact on asteroid mining. We set 3 distribution weights of the mineral resources in the group

B : $w_1=0.6$ (fund), $w_2=0.3$ (technology), $w_3=0.2$ (talents).

So the amount of mineral resources that a nation can get follows the following formula:

$$a'_i = \begin{cases} 0.6 * \frac{Fg_i}{\sum_{i=1}^n Fg_i} & \text{if invest} \\ 0.2 * \frac{Lh_i}{\sum_{i=1}^n Lh_i} & \text{if send the talent} \\ 0.3 * \frac{T_i}{\sum_{i=1}^n T_i} & \text{if employ the technology} \end{cases} \quad (12)$$

4. Conclusions

1. Friendliness to the ‘Unqualified Country’: The first model takes the impact of poor development resulted by the history on global equity into consideration. And employ different methods of allocation appropriately.

2. A Third-Party Institution’s Establishment: We structure a concept of a third-party institution which makes the model more objective. Transparency and equity are guaranteed.

3. Timeliness: In our Allocation Model, we successfully make our model advance with the development of industry. So our Allocation Model adapt to the development of the mining industry and even the whole society.

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