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Go Prospecting for Gold on Asteroids

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Abstract: *Gold rush has increasingly been flourishing with Asteroid mining in the scope, but space congestion and resources restriction could not be neglected as well. In this paper proposes a global equity model to assess the effects of resource allocation with sustainability in the scope. Our model has capabilities to deal with issues of space-based resources exploration and social development modality. We define the concept and construct a self-adaptive system which integrates social, economic, technological, ecological and cultural variables related to five aspects to measure global equity.*

Keywords: *Global equity model; Cluster analysis; Hierarchical analysis method; Asteroid mining*

1. Introduction

Asteroids are rich in mineral resources such as fuel oil and precious metals. They are relatively close to the earth and have low detection costs. The unique advantages of asteroids in space resource mining are not only beneficial to the implementation of planetary science and space resource exploration missions, but also reduce the risk of some asteroids hitting the earth [1].

The Outer Space Treaty provides plenty of opportunities to explore asteroids for the whole world [2]. However, restriction on mutual interest and non-appropriation is not be neglected. Therefore, with the background information and constraints described in the question, we need to solve the problems: How to define global equity and choose an appropriate indicator system to build a model or set of models to measure global equity.

To address these puzzles, we propose some solutions in the following ways. Define the concept of global equity. The index system is established from five aspects. The weights of the 15 secondary indicators are determined by the analytic hierarchy process. The calculation equation of the global stock index is obtained, and the 266 countries studied are divided into three categories through hierarchical clustering analysis. Describe the future vision of asteroids in terms of development technology, mining industry, benefit distribution and risk assessment. In the asteroid mining condition, we use the entropy weight method (EWM) to calculate the weights, and the visualization application shows the equality index ranking of countries. Simulate the credit default probability of private enterprises. In addition, when the mining subject is changed from the government to the private enterprise, the weight of the indicator of the Gini coefficient is increased through the AHP method.

2. Realted Work

In management psychology, Stearns Adams, an American scholar, propose the theory of equity. Besides, he claimed that employees not only care about the absolute amount of their own compensation, but also care about the amount of other people's compensation. As a consequence, employees will compare their input/output ratio with the input/output ratio of other related people. Once the two ratios are far apart, they will have a sense of unfairness, which derived from two aspects: one is the perception that they are paying too much in relation to their earnings, but the other is the perception that they are earning too little in relation to their inputs [3].

Drawing on this, we believe that in a global macro environment, where countries and regions have certain differences in rates of economic development, levels of technological development, cultural innovation capacity and social security levels. Global equity does not mean absolute equality in the distribution of resources everywhere. Importantly, the acquisition of a sense of equity is closely linked to the selection of a reference, which will be of four kinds in each country or region.

To sum up, with the goal of achieving similar results for all participants in the distribution, global

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equity is the rational allocation of resources and opportunities in the world and supports the world to truly achieve a global pattern of "good for you, good for me, good for all". Due to the premise of choosing the appropriate reference, each national or regional government and private enterprises with the ability to compare with other relevant objects.

3. Method

In order to construct a highly applicable indicator system, defining a certain logical relationship between the selected indicators is of great significance. Study the literature on global carbon emission rights allocation, the evaluation system of comprehensive city strength could be illustrated. We establish a global equity indicator system from five aspects: social, ecological, cultural, science and innovation, and economic [4]. After determining the indicator framework, we collected data from the World Bank, (GAPMINDER database) and national statistical offices. According to the level of productivity development as well as gross national product and gross domestic product per capita, we selected a total of 266 countries and classified them into three categories: countries with high income levels, countries with high income levels, a median income.

3.1. Data Pre-processing

As is known to us, here are many factors in measuring global equity indicators. Some countries inevitably have missing values on some indicators. We use the following approach so as to address this issue.

After the processing of missing data values is completed, we can obtain complete data for about 266 countries for a total of 10 years from 2010 to 2020.

We used descriptive statistics to find outliers in some countries that deviate from the mean by more than twice the standard deviation on some indicators. For data with significance level α <0.01, we removed them as outliers and applied the missing value treatment method described above. We also found some data that deviated significantly from reality, and we discarded them as well. For example, the percentage of forest area to land area is greater than 100%, which is obviously out of reality.

3.2. Data Normalization

The so-called raw matrix normalization is to unify all the indicator types into benefit-based indicators. The types of indicators are shown in Table 1.

Table 1: Types of attributes

Attributes Name	Attributes Features
Benefit Attributes	the larger, the better
Cost Attributes	the smaller the better
Intermediate Attributes	the closer to a certain value, the better
interval Attributes	best in a certain range

Cost-based indicators are transformed into benefit-based indicators: max-x. Interval-type indicators into benefit-type indicators: a set of intermediate-type indicator series and the best interval is [a, b], then the formula for forwarding is as follows:

$$M = max\{a - min\{x_i\},, max\{x_i\} - b\},\ \widehat{x_i} = \begin{cases} 1 - \frac{a-x}{M}, & x < a \\ 1, & a \le x \le b \\ 1 - \frac{x-b}{M}, & x > b \end{cases} \quad (1)$$

The purpose of standardization is to eliminate the influence of different metrics. Suppose there is an object to be evaluated, and the normalization matrix of the evaluation indicators (which have been normalized) is as follows:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \quad (2)$$

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Then, we denote the normalized indicator weight as Z, each element in Z is as follow:

$$Z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \tag{3}$$

3.3. Determination of Index Weights Using Hierarchical Analysis (AHP)

The decision problem is decomposed into three levels, the uppermost level is the target level M, which is to select the most suitable key indicators to evaluate the global equity level; the lowermost level is the program level C, which is 15 influencing factors: the employment level of residents, the level of social infrastructure construction, the level of social welfare, the level of urban environment, the level of urban greening, the level of ecological function, etc. The middle layer is the guideline layer B, which includes social aspects, ecological aspects, cultural aspects, science and technology innovation aspects, and economic aspects. The indicator system is shown in Figure 1.

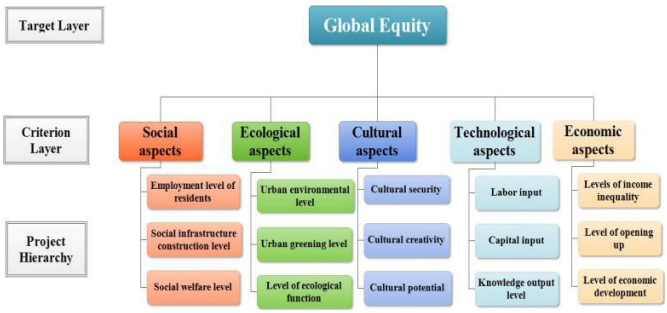

Figure 1: AHP index framework

By constructing the judgment matrix, we can obtain the weight vector, maximum eigenvalue and consistency index, as shown in the Table 2 below.

Table 2: Indicator weights of criterion level and scheme level

Level B1 / Level C	B1 q2	Level B2 / Level C	B2 q3
C1	0.5816	C4	0.5396
C2	0.1095	C5	0.2970
C3	0.3090	C6	0.1634
λ_{max}	3.0037	λ_{max}	3.0092
CR_j	0.0036	CR_j	0.0088

Level / Level	B3 q4	Level / Level	B4 q5	Level / Level	B5 q6
C7	0.5816	C10	0.4444	C13	0.2255
C8	0.1095	C11	0.4444	C14	0.1007
C9	0.3090	C12	0.1111	C15	0.6738
λ_{max}	3.0037	λ_{max}	3.0000	λ_{max}	3.0858
CR_j	0.0036	CR_j	-8.5402e-16	CR_j	0.0825

Level M / Level	M q1	Level M / Level	M q1
B1	0.1277	B5	0.2467
B2	0,2681	λ_{max}	3.0092
B3	0.0754	CR_j	0.0910
B4	0.2820		

From the results of the hierarchical analysis model, we can calculate the influence weight of each indicator at the criterion level and the program level on the total indicator "global equity", and we summarize the final results as shown in Table 3.

Table 3: Indicator weights

	Indicator	Weight		Indicator	Weight
Social aspects (0.1277)	ELR	0.5816	**Cultural aspects** (0.0754)	CS	0.5816
	SICL	0.1095		CC	0.1095
	SWL	0.3096		CP	0.3090
Ecological aspects (0.2681)	UEL	0.5396	**Technological aspects** (0.2820)	LI	0.4444
	UGL	0.2970		CI	0.4444
	LEF	0.1634		KOL	0.1111
	Indicator			**Weight**	
Economic aspects (0.2467)	LII			0.2255	
	LOU			0.1007	
	LED			0.6738	

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We denote w_{ij} as the weight of the j-th second-level indicator under the i-th first-level indicator, and x_{pj} as the standardized value of the j-th second-level indicator in the p-th country.

We define the fairness index E_p to describe the social fairness level of the p-th country as:

$$E_p = \sum_{i=1}^{5} \sum_{j=1}^{15} w_{ij} \cdot x_{pj} \tag{4}$$

Since the indicator data of some countries are difficult to obtain, we finally choose 266 countries around the world for analysis, and based on the indicator data of individual countries and the corresponding weights, we can calculate the equity index of each country. By clustering the GDP per capita of 266 countries, we divide all countries into three categories, including high living standard of residents, medium living standard of residents and low living standard of residents. Distribution of equity index for 266 countries is shown in Figure 2 below.

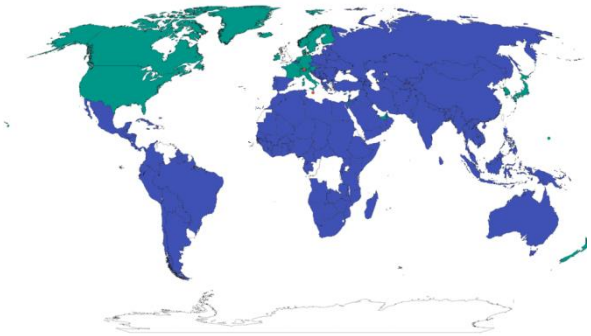

Figure 2: Distribution of countries of category Ⅰ, Ⅱ and Ⅲ

The red area represents countries with high living standards of residents, which we call Class I countries, the green area represents countries with medium living standards of residents, which we call Class II countries, and the blue area represents countries with low living standards of residents, which we call Class III countries. After compiling the literature, we found that the equity index of countries with lower living standards of their residents is more representative of the global equity index. Countries with higher GDP per capita have higher income levels and better livelihood security for their residents, and the government will have more money to spend on various aspects of the country, and residents tend to have a stronger sense of equity, But the opposite is true for countries with lower GDP per capita. Therefore, in order to accurately measure the global equity situation, we will give more weight to countries in category III, and the weights of the three types of countries are expressed as λ_1, λ_2, λ_3, $\lambda_1 < \lambda_2 < \lambda_3$. We define the global equity index as follows:

$$F = \sum_{i=1}^{n_{Ⅰ}} \lambda_1 E_{Ⅰi} + \sum_{i=n_{Ⅰ}}^{n_{Ⅱ}} \lambda_2 E_{Ⅱi} + \sum_{i=n_{Ⅱ}}^{n_{Ⅲ}} \lambda_3 E_{Ⅲi} \tag{5}$$

3.4. Application of the Global Equity Model

When the global equity model is constructed, we need to validate the model. We divide 266 countries into Northern Hemisphere countries and Southern Hemisphere countries according to their geographical locations, and calculate the global equity index separately with F_B, F_N.

$$F_B = \sum_{i=1}^{n_{Ⅰ}} \lambda_1 E_{Ⅰi} + \sum_{i=n_{Ⅰ}}^{n_{Ⅱ}} \lambda_2 E_{Ⅱi} + \sum_{i=n_{Ⅱ}}^{n_{Ⅲ}} \lambda_3 E_{Ⅲi} \tag{6}$$

$$F_N = \sum_{i=1}^{n_{Ⅰ}} \lambda_1 E_{Ⅰi} + \sum_{i=n_{Ⅰ}}^{n_{Ⅱ}} \lambda_2 E_{Ⅱi} + \sum_{i=n_{Ⅱ}}^{n_{Ⅲ}} \lambda_3 E_{Ⅲi} \tag{7}$$

After calculation, we found that the global equity index of the northern hemisphere is 99.08 greater than the global equity index of the southern hemisphere is 82.76, which means that the equity level of the northern hemisphere is generally higher than the equity level of the southern hemisphere. We found through the survey literature that the residents of the Southern Hemisphere generally lag behind the Northern Hemisphere in terms of living standard. Therefore, the global equity model we developed is practical and consistent with the actual situation, and the model is validated.

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4. Conclusion

In order to evaluate the effect of resource allocation, we constructed an indicator system that integrates five aspects: social, economic, scientific and technological, ecological, and cultural. The influence weight of 15 secondary indicators on the total indicator "global equity" can be calculated from the results of the hierarchical analysis model, and through the cluster analysis of the GDP per capita of the countries studied, we divide all countries into three categories and find that the equity index of countries with lower living standards are more representative of the global equity index.

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