A study of Global Equity based on AHP & EW Multi-attribute Decision Model

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Abstract. With the shortage of Earth's resources, asteroid mining has received much attention. However, there is no specific policy to address the impact of asteroid mining on global equity, so this paper proposes a targeted mathematical modeling solution-AHP&EM multi-attribute decision model. First, this paper calculates the weights of these different aspects in the model using entropy weights (EW) and hierarchical analysis (AHP), successfully constructs a global stock valuation model, and finds that the global stock index is gradually improving. In addition, this paper designs a scoring model and evaluates the optimal solution using the Pythagorean hesitant fuzzy operator (PFHS) and concludes that the agency model is most beneficial to the growth of the global equity index, while the equity system and tax planning are most suitable for the current model and most beneficial to the global equity.

Keywords: Pythagorean Hesitate Fuzzy Set, Entropy Weight Method, Analytic Hierarchy Process.

1. Introduction

The United Nations is an international organization established by humanity to promote global peace and reduce inequality [1]. Over the decades of its existence, the United Nations has successfully prevented thousands of incidents of inequality through a series of laws and constraints [2]. Among them, the Outer Space Treaty, signed in 1967 as the basis of international space law, has successfully safeguarded the basic interests of countries in space development and provided a legal basis for their access to space projects [3-5]. However, with the advent of the 21st century, the spurt of scientific and technological progress has made the decades-old Outer Space Treaty unable to fully address the fairness of all human development and exploration projects in space, one of which is the issue of asteroid mining that has emerged in the last decade.

Currently, the international community does not have specific laws and policies to address these issues [6-8]. Therefore, it is necessary to establish a scientific and accurate evaluation system to evaluate world equity and study the impact of asteroid mining on world equity, to propose improvements and recommendations to the existing related laws and policies.

Therefore, this paper firstly constructs a model for global equity valuation, AHP&EM multi-attribute decision model, after analyzing the problem and finding that the global equity index is gradually improving. In addition, this paper also uses the Pythagorean fuzzy operator of hesitation (PFHS) to build a scoring model to evaluate the optimal solution of this global equity evaluation model and draws relevant conclusions to guide the global equity structure evaluation. The overall idea of the article is shown in Figure 1 below.

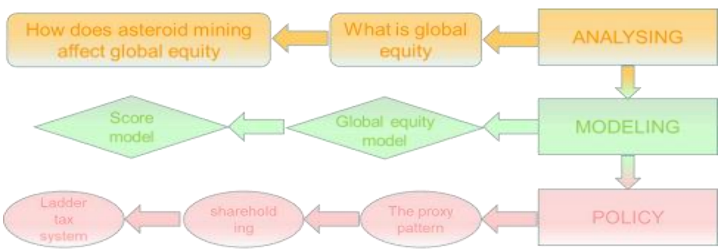

Figure 1. The general idea of the paper

2. Evaluation Model of Global Equity

2.1. The establishment of simulation model

To realize the discussion of the world equity model, we have made comprehensive considerations that require appropriate assumptions for better simplification and understanding. These assumptions are as follows.

(1) We assume that the world as a whole will become more equitable as history progresses.

(2) We assume that developed countries as a whole are more equitable than developing countries.

(3) We assume that indicators such as GDP and development indices of the world's countries will not change much in recent years. In other words, the change from developing countries to developed countries will not happen in an instant, and the nature of countries will not change suddenly. The economic level and international status of a country will not change in the short term. Especially at the time when the epidemic is ravaging the world, global economic development has come to a standstill and dozens of countries are even experiencing economic regression and a decline in the standard of living of their people.

(4) we assume that the asteroid mining technology has broken through to solve the cost and profit issues and ensure safety.

(5) The data we have collected is correct. We collect data from the official websites of major institutions in the world, such as the United Nations [9], the World Bank [10], the World Monetary Fund [11], and the Oxford University database website [12].

2.2. Data acquisition and pre-processing

Accurate and sufficient data are the basis and necessary condition for building a correct model. In order to ensure the authenticity of our study as much as possible, our data were collected from the websites and platforms of major official institutions for 20 developed and developing countries from all continents of the world (except Antarctica).

There are many factors to measure global equity. In this paper, three factors, economic, technological and social, were extracted from the many factors as the main parameters of the study. Under each main attribute, we find three sub-attributes to refine the model. The specific attribute table for assessing the model is shown in the following table 1:

Table 1. Module evaluation specific attributes

Factors	Attribute	Attribute classification
Economy (ECO)	Gross domestic product (GDP)	Benefit type
	Gross national income as measured by purchasing power parity (GNIP)	Benefit type
	The gini coefficient (GINI)	Cost type
Scienc and Technology (SAT)	Proportion of R&D expenditure in GDP (PRDG)	Benefit type
	R&D researchers (per million) (RDP)	Benefit type
	Sci-tech journal articles(SJA)	Benefit type
Society (SOC)	Public education spending as a percentage of GDP(PESG)	Benefit type
	Proportion of women seats in international parliaments (WSI)	Interval type
	The unemployment rate (UER)	Cost type

The attribute types are generally effective benefit type, cost type, fixed type, deviation type, interval type, deviation interval type, etc. The relationship diagram of these types is shown in Figure 2. The benefit type attribute means that the larger the attribute value is, the better. A cost-type attribute means that the smaller the value of the attribute, the better. Fixed type attribute means that the closer the attribute value is to a fixed value, the better. Deviation attribute means that the more the attribute value deviates from a fixed value B, the better. An interval attribute is an attribute value that is closer to a fixed interval [Q1, Q2], including falling into the interval), the better. The deviation interval attribute is the more the attribute value deviates from a fixed interval [Q1, Q2], the better.

Among these attributes: Benefit type: GDP, GNIP, PRDG, RDP, SJA, PESG. Cost type: GINI, UER. Interval type: WSI.

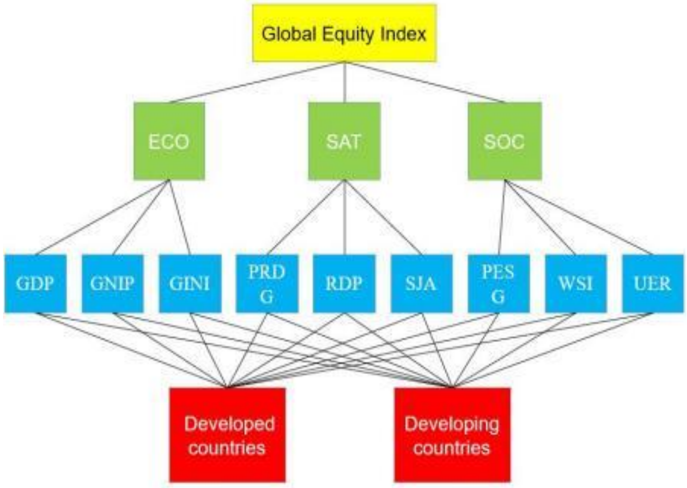

Figure 2. Attribute relationship type diagram

2.3. Model Solution

Due to different attribute types, we must normalize them. For different attribute types, we also have different normalization methods.

If the attribute value is benefit type, then:

$$r_{ij} = \frac{a_{ij} - \min_i a_{ij}}{\max_i a_{ij} - \min_i a_{ij}} \tag{1}$$

If the attribute value is cost type, then:

$$r_{ij} = \frac{\max_i a_{ij} - a_{ij}}{\max_i a_{ij} - \min_i a_{ij}} \tag{2}$$

We selected 10 developed and 10 developing countries from 20 continents using the 2020 data as the standard(The 2021 data are still not released for some countries). After summarizing the data, the statistics are as following figure 3.

Index	Developed Country	Developing Country
GDP	3.94508E+13	1.93004E+13
GNI	4.38955E+13	1.55999E+13
GINI	34.65	44.84
RDP	4371.600373	859.830205
PRDG	0.2348326	0.0738087
SJA	1044105	277407
WSI	27.03887176	31.2894088
PESG	13.71630417	16.93471323
UER	6.114200044	12.79099979

Figure 3. Raw data for indicators in developed and developing countries

In the entropy weight method (EW), the entropy weight essentially reflects the degree of difference in information provided by attributes and the relative strength of competition among attributes, rather than the actual importance of attributes. In the hierarchical analysis method (AHP), the comparison judgment matrix is given entirely by expert experience, which is difficult to exclude the influence of human factors and cannot solve the problem of high accuracy.

The entropy weighting method is a quantitative synthesis of multiple indicators method for decision making, and the specific steps of applying the entropy weight method to calculate the weights are following:

Construct a combined decision evaluation matrix of n evaluation objects and k attribute evaluation indicators array A.

$$A=\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1k} \\ x_{21} & x_{22} & x_{23} & x_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nk} \end{bmatrix} \tag{3}$$

The data x_{ij} in the multi-attribute evaluation matrix A were standardized using the deviation standardization method. standardization process and the standardized values are

$$y_{ij}=\frac{x_{ij}-\min(X_i)}{\max(X_i)-\min(X_i)} \tag{4}$$

The weight p_{ij} of the i-th data under the j-th attribute component is calculated as

$$p_{ij}=\frac{y_{ij}}{\sum_{i=1}^{n} y_{ij}} \tag{5}$$

Calculate the entropy value of the j-th attribute component e_j as

$$e_j=-k\sum_{i=1}^{n} p_{ij}\ln(p_{ij}) \tag{6}$$

The coefficient of variation g_j for the j-th attribute component is calculated as

$$g_j=1-e_j \tag{7}$$

Finally, the weight coefficient ωj of the j-th attribute component is calculated as

$$\omega_j=\frac{g_j}{\sum_{n=1}^{k} g_j} \tag{8}$$

The entropy weighting method is objective and adaptable, but the traditional entropy weighting decision model also has a problem when all the ownership values converge, small differences can affect the multiplication of the weight values, which can lead to some indicators being assigned weights that do not match their importance, and thus affect the judgment of the final decision results. Therefore, to avoid the possible bias in the results from a single weighting method, the modeling algorithm in this paper is to calculate the weights of each of the three macroscopic indicators by using the entropy weight method (EWM) integrated with the hierarchical analysis method (AHP) after the normalization of the parameter indicators, as shown in Figure 4 below.

$$\mathrm{GEI}=0.231{*}\mathrm{E}+0.357{*}\mathrm{T}+0.412{*}\mathrm{S} \tag{9}$$

Index	Developed Country	Developing Country
GDP	0.6715	0.3285
GNI	0.7386	0.2614
GINI	0.4360	0.5640
RDP	0.8356	0.1644
PRDP	0.7609	0.2391
SJA	0.7901	0.2099
WSI	0.4655	0.5345
PESG	0.4477	0.5523
UER	0.3232	0.6768

Figure 4. Calculated weights of the three macro indicators

2.4. Model Application

Based on the model developed in section 2.3 above, we apply it to the period 1997-2020. As can be seen in Figure 5 that the level of equity in the world has been increasing in the past 23 years. These results are consistent with people's subjective perceptions.

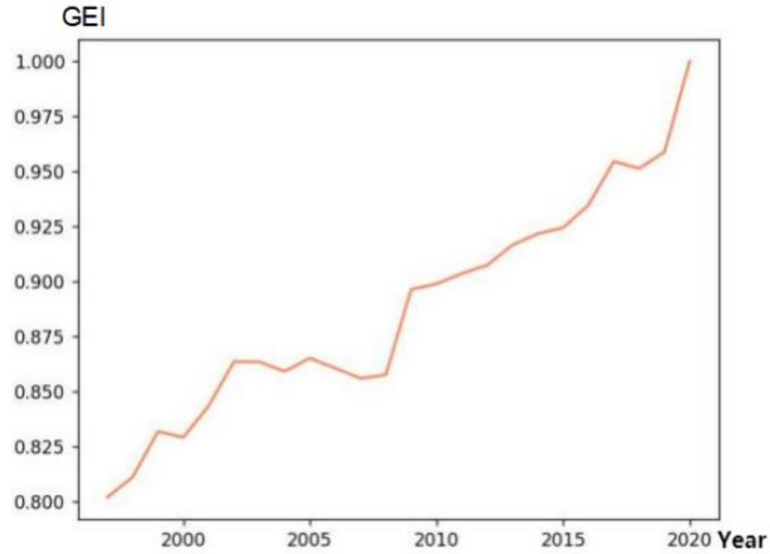

Figure 5. Application of the model to the period 1997-2020

3. Score Model

3.1. The modeling process

With the increasing scarcity of resources on Earth, asteroid mining technology is coming into the limelight, but with it comes a variety of questions, the most widely discussed of which is whether asteroid mining will affect current global equity. If so, what can be done about it? We, therefore, need a comprehensive global equity model to address these questions.

We first use the data in table 2 to build the Pythagorean fuzzy decision matrix of indecisiveness.

Table 2. Module evaluation specific attributes

	ECO	SAT	SOC
Monopoly	<{0.3,0.8},{0.4}>	<{0.6,0.8},{0.4,0.5}>	<{0.7,0.8},{0.4,0.5}>
Together	<{0.7,0.8},{0.3,0.4}>	<{0.3,0.4,0.5},{0.7}>	<{0.3,0.4},{0.7,0.8}>
Proxy	<{0.4,0.5},{0.6}>	<{0.4,0.5,0.6},{0.5}>	<{0.7,0.8},{0.4,0.5}>

Then use the integration operator PHFWA to integrate each solution.

a 1 = < { 0. 5896, 0 . 6515, 0. 6972, 0. 6538, 0. 7035, 0. 7409, 0. 6337, 0. 6871, 0. 7270, 0. 6891, 0. 7326, 0. 7657, 0. 6575, 0. 7065, 0. 7435, 0. 7084, 0. 7487, 0. 7795, 0. 6923, 0. 7353, 0. 7680, 0. 7369, 0. 7726, 0. 8000}, { 0. 4000, 0. 4349, 0. 4136, . 4497} >

a 2 = < { 0. 5059, 0. 5557, 0. 5272, 0. 6661, 0. 5146, 0. 5631, 0. 5353, 0. 5807, 0. 5265, 0. 5732, 0. 5464, 0. 5903, 0. 5420, 0. 5865, 0. 5609, 0. 6028, 0. 5497, 0. 5932, 0. 5682, 0. 6091, 0. 5603, 0. 6023, 0. 5781, 0. 6177}, { 0. 4681, 0. 5139, 0. 4921, 0. 5403, 0. 4887, 0. 5366, 0. 5138, 0. 5642 }>

a 3 = <{ 0. 6863, 0. 7551, 0. 7320, 0. 7892, 0. 6928, 0. 7599 , 0. 7373, 0. 7932, 0. 7016, 0. 766 4, 0. 7446, 0. 7987, 0. 6928, 0. 7599, 0. 7373, 0. 7932, 0. 6991, 0. 7646, 0. 7425, 0. 7972, 0. 7076, 0. 7710, 0. 7496, 0. 8025}, { 0. 4003, 0. 4353} >

Finally, the scoring function is derived to find the optimal: scheme Sa1 = 0.3308, Sa2 = 0. 1592, Sa3 = 0.3873.

From the results, we can see that the agent model has the highest score, and combined with the internal analysis of the Pythagorean hesitation fuzzy decision matrix, we can conclude that the agent model is the best.

3.2. Sensitivity Analysis

We use the constrained tolerance range of the 3D conical region and select three weight values in the operator model, as shown in Figure 6. A three-dimensional vector (E, T, P) is computationally constructed, and the direction vector of the vector is used to find the straight line L($\frac{E}{0.231}=\frac{T}{0.357}=\frac{S}{0.412}$). With L as the axis, the angle between the bus and the axis is 0.5°, the fault-tolerant cone generates the equation of the bus calculation, and the result is 0.22765 < WE < 0.26382, 0. 17386 < WT < 0.21035, 0.53425 < WS < 0.57364. The error tolerance float for this is: 0.22765<W1<0.26382, 0.33585 <W2<0.37452, 0.39243<W3<0.43625.

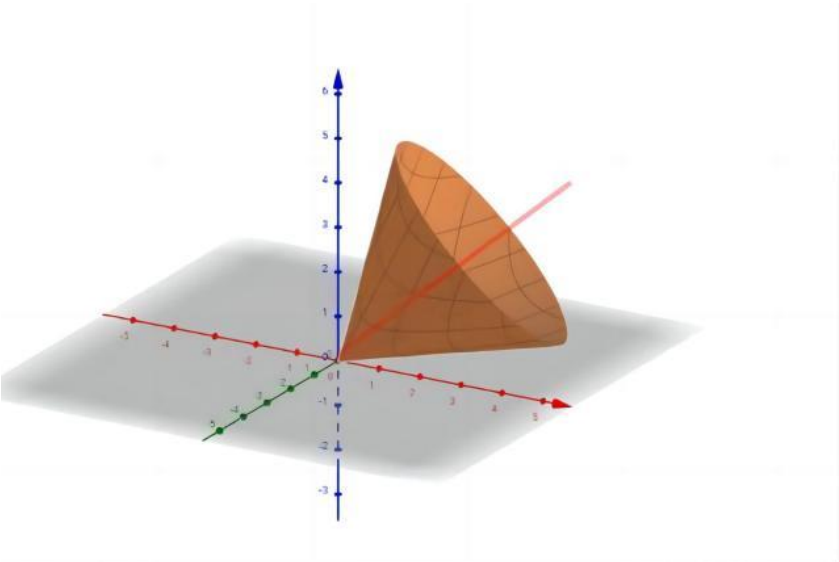

Figure 6. The 3D conical region

4. Conclusions

In this paper, three factors, economic, technological, and social, are considered in the framework of the global equity model. The WAA operator (weighted average operator) and AHP&EM multi-attribute decision model are used as the main models, and the entropy minimization principle and hesitation fuzzy index entropy are used to determine the weight vector of evaluation attributes. The Lagrangian interpolation method is also used to deal with the small amount of data defects found in the data collection to ensure the true validity of the data. The analytical method established in this paper deeply answers the three core questions of who mines, who invests in mining, and who gets the benefits, to successfully address the impact of mining on world equity. The policies obtained through this analytical approach can ensure maximum global equity in the case of simulated world equity models.

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