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Study of Global Equity and the Distribution of Asteroid Resources

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Abstract

In recent years, asteroid mining has gradually entered people's field of vision, because asteroids have extremely rich mineral resources. However, with the exploration of space resources, global equity is increasingly becoming a concern. Therefore, we have built a suite of measurement models to measure global equity system. After solving the problem of global equity measurement, we conceived the future vision of asteroid mining industry, and we hope that asteroid resources can be distributed fairly. We use SWOT model to analyze asteroid mining and predict its future trend. Finally, we discussed the policy of asteroid mining. We intend to establish resource account book, international tax policy and extra reward policy to promote the fair distribution of asteroid resources and realize the equal development of all countries in the world. Considering the current international situation, we predict that the implementation of these policies is difficult to be realized soon.

Keywords

FCE; AHP; Gini coefficient; SWOT model; Grey Relational Analysis.

1. Introduction

1.1. Problem Background

In recent years, with the development of science and technology and the shortage of existing resources in the earth, people put the spotlight on the asteroid that are rich in scarce resources, if we can fully use the asteroid mining resources, there is no doubt that we can solve the problem of survival of human. However, when people explore the space resources, the global equity has become a concern which is worth discussing.

Global equity belongs to the philosophical category, so now there is no ready-made standard to measure how fair the world is. Therefore, it is important to establish a suite of model that takes all factors into account and is able to measure global equity. In this paper, we comprehensively consider many factors, and finally measure global equity with Fuzzy Comprehensive Evaluation model. On this basis, we focus on research the future of asteroid and studying the impact of asteroid mining resources on global equity.

Furthermore, based on the model, we propose and analyze policies that encourage asteroid mining enterprises to develop in a way that promotes global equity, so that the world is in a relatively fair state, thus benefiting all mankind.

2. Assumption and Notation

2.1. Assumption

To simplify the problem, we make the following assumptions, each of which has a valid reason.

• Assuming that the data we found in the Internet is reasonable and real.

Justification: We spent sufficient time searching for data in formal and official databases, which are in line with people's cognitive rules.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202301_6(1).0013

• Assuming that the 12 countries we selected can represent the developed countries, medium countries and backward countries all around the world.

Justification: We considered many indicators to cluster countries, and we can think that this division is reasonable and regular. We use sampling method to extract from the clusters separately, eliminating the interference of human factors. Through analysis, we believe that the country we have chosen is typical and can represent most countries in the world.

• Assuming that the factors we didn't mention have little influence on the global equity system.

Justification: When measuring global equity, we measured the influence of economic, environmental resources, politics and culture, and we believe that we have considered most factors that affect global equity. Therefore, we dismiss factors not mentioned.

• Assuming that the influence of extreme events can be ignored.

Justification: The possibility of extreme events is very small, so we don't consider the influence of extreme events when predicting the future prospects of asteroid mining.

• Assuming that natural resources can be distributed fairly.

Justification: Absolute fairness does not actually exist, but in order to study the impact of asteroid resources exploitation on global equity, we assume that resources can be distributed fairly according to our rules.

2.2. Notation

The key mathematical notations used in this paper are listed in Table 1.

Table 1. Notations used in this paper

Symbol	Description
E	Economy
R	Environmental resources
P	Politics
C	Culture
G	Gini coefficient
M	fuzzy comprehensive judgment matrix of primary factors
$y(X_0, X_i)$	grey correlation degree of X_0 and X_i

3. Fuzzy Comprehensive Evaluation Model

Today's world is complicated because different countries have different national conditions. Developed countries have an significant edge over backward countries in terms of economic development, scientific and technological level, etc. Therefore, the appeal for global fairness aims to reduce absolute poverty, narrow the poverty gap in developed countries and developing countries caused by the existing global economic order, and give everyone a chance to survive, develop and enjoy resources in a healthy environment. In order to help better measure global equity, we urgently need to establish a model to evaluate global equity. As a result, we use the fuzzy comprehensive evaluation model to quantify the degree of global equity from four dimensions: economy, environmental resources, politics and culture.

3.1. Data Preparations

In order to measure the global equity, we collected the data of 98 countries all around the world concerning income, primary completion rate, happiness index, the number of Internet user, industry. Next, we used K-means++ clustering algorithm to divide these 98 countries into three categories named first-class countries, middle-class countries and backward countries and

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chose four countries from every categories as typical representatives. We can simplify the data and make our work more efficient in this way. The following shows the flow chart of K-means clustering algorithm:

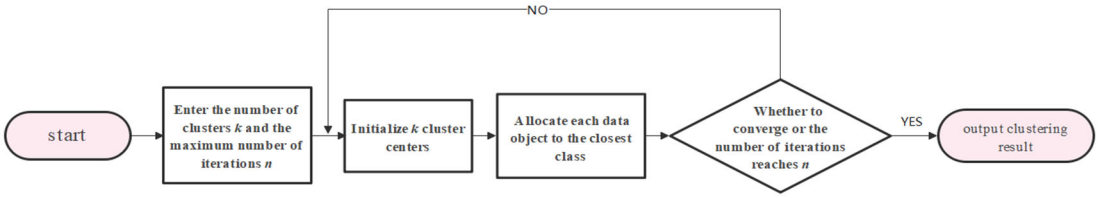

Figure 2. Flow chart of K-means clustering algorithm

• First of all, in order to eliminate the influence of data dimension, we standardized the date according to this formula:

$$z_i = \frac{x_i - \bar{x}}{\sigma_i}$$

Next, we took advantage of SPSS software to cluster and got 26 first-class clusters, 34 second-class clusters and 38 third-class clusters.

The final cluster center

	1	2	3
Income	1.02913	-.83002	.03851
Industry	-.66959	-.21419	.64979
Happiness index	1.03082	-.89958	.09959
The amount of computer user	.88931	-1.12657	.39951
Primary completion rate	.45424	-.84608	.44623

The distance between the final cluster centers

clustering	1	2	3
1		3.626	1.957
2	3.626		2.549
3	1.957	2.549	

We randomly sample from the first-class cluster to represent first-class countries, from the second-class cluster to represent middle-class countries, and from the third-class cluster to represent backward countries. The 12 selected samples are shown below.

countries	1	2	3
1	United States	Armenia	Algeria
2	Australia	Bolivia	Albania
3	Italy	Egypt	Iran
4	Germany	Tanzania	Mozambique

Here is a map showing the 12 countries we select.

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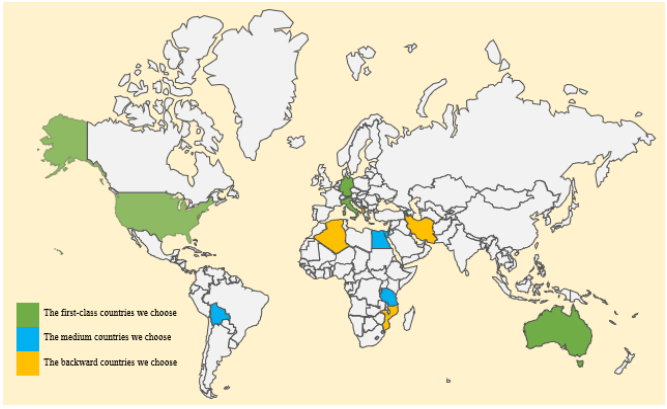

Figure 3. Map for countries we choose

We surveyed 12 countries and completed the standardization of the data and our following calculation and model solving are all based on the collection of these data.

3.2. The Discussion of Main Factors and Comments

3.2.1. Determine the factor set

(1) the primary factor

We think that global equity means that the gap between the rich and the poor in developing countries and developed countries is narrow, and all countries in the world enjoy equal rights to allocate global natural resources, and eventually all countries in the world are in a state of long-term stability and peace. To this end, we should consider four conditions together: Economy, environmental resources, politics and culture, so there are four primary factors as shown:

$$U = [E, R, P, C]$$

where E, R, P, C stand for economy, environmental resources, politics and culture respectively.

(2) the secondary factors

There are several secondary factors under each primary factor. Our fuzzy comprehensive evaluation is based on four primary indicators, and several secondary indicators determine the primary indicators as shown in figure#.

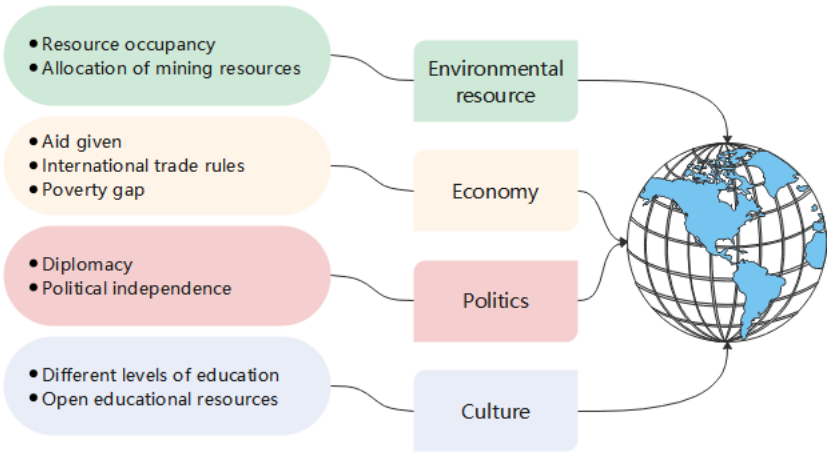

Figure 4. Framework of factors

Next, we will explain it in detail.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202301_6(1).0013

◆ Economy is an important index to measure global equity. Only when the gap between rich and poor in developed countries and developing countries is small can we consider that human society has achieved global equity relatively. We choose these factor as the secondary factors of economy: aid given (E1), international trade rules (E2) and the poverty gap(E3).

◆ The rational distribution and utilization of environmental resources make considerable contribution to global equity. Among them, resource occupancy (R1) and allocation of mining resources (R2) are both factors related to environmental resources. Accordingly, we choose them as the secondary factors of environmental resources.

◆ Politics plays an increasingly important role in global equity under the trend of globalization. Accordingly, we choose diplomacy (P1) and political independence (P2) as the secondary indicators of politics.

◆ Under the wave of Community of Shared Future for Mankind, culture has attracted more and more attention and played an increasingly important role in global equity. Therefore, we choose the different levels of education (C1) and the open educational resources (C2) as the secondary factors of culture.

3.2.2. Determine the comment set

Since we have determined the factor set, now we will proceed to carry out the second step: determine the comment set of fuzzy comprehensive evaluation. In this part, we set four comments on global equity: absolutely fair, relatively fair, relatively unfair and unfair.

$$V = [v1 \quad v2 \quad v3 \quad v4]$$

where v1, v2, v3, v4 stand for absolutely fair, relatively fair, relatively unfair and unfair respectively.

3.3. Determine the Weight of Each Factor

Usually, each factor in the factor set plays a different role in the fuzzy comprehensive evaluation model, so we use AHP to determine the weight of each factor.

Analytic hierarchy process (AHP) is a method to quantify the weight of decision criteria based on the full study of human thinking process. Taking the primary factors as an example, we use this method to determine the weights of other secondary factors. The following steps are:

• select factors

We have previously determined the first level factors of fuzzy comprehensive evaluation: environmental resources equity, economic equity, political equity and cultural equity. We will analyze the factors at this level hierarchically to determine the weight.

• pairwise comparisons between different factors

After comprehensively considering the relationship among economy, environmental resources, politics and culture, and comparing them in pairs, we have determined the importance of each factor:

Economic equity≥political equity≈environmental resources equity≥cultural equity

• fill in the comparison matrix

	E	P	R	C
E	1	2	3	4
P	1/2	1	2	3
R	1/3	1/2	1	2
C	1/4	1/3	1/2	1

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202301_6(1).0013

where E, P, R, C represent economic equity, political equity, environmental equity and cultural equity respectively.

• consistency test

We can easily calculate the maximum eigenvalues of the matrix λ_{max} =4.0310

$$CI = \frac{\lambda_{max} - n}{n-1}$$

$$CR = \frac{CI}{RI}$$

where RI = 0.89 when n = 4. For the above comparison matrix, we obtain CR = 0.0116< 0.1, thus the comparison matrix is acceptable.

•calculate the weight

Having passed the consistency test, we get the weight distribution among primary factors by eigenvalue method, which is a fuzzy vector on U, denoted as A=[0.467,0.277,0.161,0.095].

Using the same method, we get the weights of different factors at all levels, as shown in the figure below:

Factor(1)	*Weights*	*Factor(2)*	*Weights*
Economic equity	**0.467**	**Aid given**	**0.46**
		International trade rules	**0.382**
		Poverty gap	**0.158**
Environmental resource equity	**0.161**	**Resource occupancy**	**0.333**
		Allocation of mining resources	**0.667**
Political equity	**0.277**	**Political independence**	**0.875**
		Diplomacy	**0.125**
Cutural equity	**0.095**	**Different levels of education**	**0.25**
		Open educational resources	**0.75**

Figure 5. Weights of each indicator

3.4. Determine the Fuzzy Comprehensive Judgment Matrix

For the factor, the membership degree of each comment is a fuzzy subset on V. Now, we will use some methods to evaluate each factor.

3.4.1. Determine the membership degree

In the fuzzy comprehensive evaluation model, it is important to measure the membership degree of each factor to each comment in the comment set. Generally, fuzzy statistics method and assignment method can be used to determine it. Next, I will take the poverty gap, resource occupancy and allocation of mining resources as examples to show how to determine the membership degree of factors to comments.

• In order to study the membership degree of poverty gap to each comment, we quantify the abstract concept of poverty gap as income gap and introduce the concept of Gini coefficient.

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Gini coefficient is an index to judge the fairness of annual income distribution according to Lorenz curve, which is a proportional value between 0 and 1. The greater the Gini coefficient, the more unfair it is. [1]

(i) determine the membership function

Organizations such as the United Nations Development United Nations Development Program (UNDP) stipulate that if Gini coefficient is lower than 0.2, the index is extremely low; 0.2-0.29 indicates that the index level is low; 0.3-0.39 means in the index grade; 0.4-0.59 indicates that the index level is high; 0.6 or above indicates that the index level is extremely high [2]. Therefore, we decided to use the assignment method to determine the membership function and define the following evaluation criteria:

Degree	Absolutely fair	Relatively fair	Relatively unfair	unfair
Gini coefficient	0.2	0.3	0.5	0.6

The four trapezoidal distributions are:

$$E_{31}=\begin{cases}1, & x\leqslant 0.2,\\ \dfrac{0.3-x}{0.3-0.2}, & 0.2<x<0.3,\\ 0, & x\geqslant 0.3.\end{cases}\qquad E_{32}=\begin{cases}0, & x\leqslant 0.2,\\ \dfrac{x-0.2}{0.3-0.2}, & 0.2<x\leqslant 0.3,\\ \dfrac{0.5-x}{0.5-0.3}, & 0.3<x<0.5,\\ 0, & x\geqslant 0.5.\end{cases}$$

$$E_{33}=\begin{cases}0, & x\leqslant 0.3,\\ \dfrac{x-0.3}{0.5-0.3}, & 0.3<x\leqslant 0.5,\\ \dfrac{0.6-x}{0.6-0.5}, & 0.5<x<0.6,\\ 0, & x\geqslant 0.6.\end{cases}\qquad E_{34}=\begin{cases}0, & x\leqslant 0.5,\\ \dfrac{x-0.5}{0.6-0.5}, & 0.5<x<0.6,\\ 1, & x\geqslant 0.6.\end{cases}$$

(ii) calculate the value of global Gini coefficient[2]

We collected the data of the population and gross national income of the above 12 countries in 2020, and used Excel software to get the percentage of each group's population to total population P, the percentage of each group's income to the total income W, the cumulative percentage of population Xi and the cumulative percentage of income Yi, and drew the following Xi-Yi Lorenz curve chart. If Lorentz curve coincides with absolute equality line A, it means that global income distribution is completely fair; On the contrary, if the area below Lorenz curve B is zero, the global income distribution is extremely unfair. The trapezoidal area method can be used to express the Gini coefficient: the smaller the radian of Lorentz curve, the smaller the Gini coefficient, which means the distribution is fairer; The larger the radian of Lorenz curve, the larger the Gini coefficient, which means the distribution is more unfair.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202301_6(1).0013

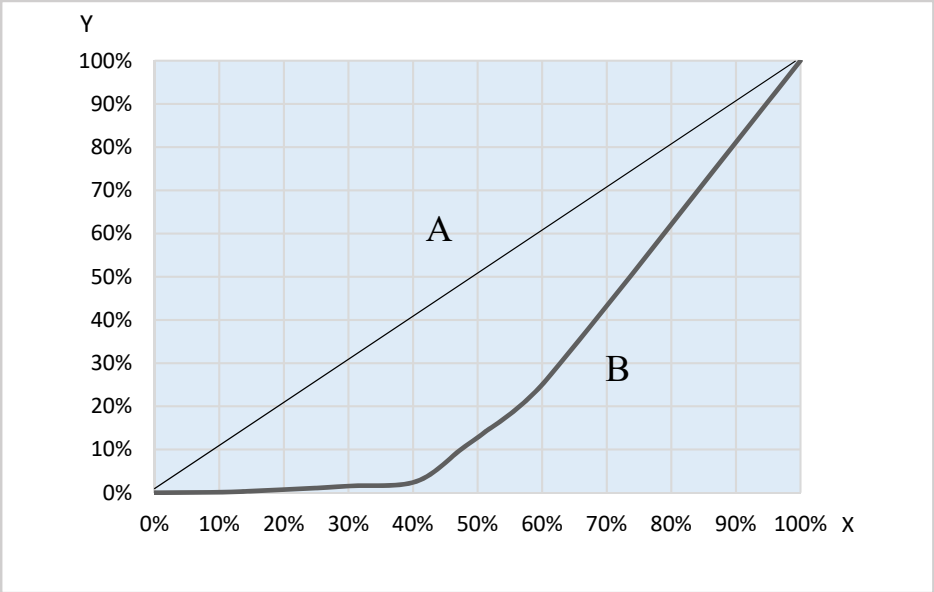

Figure 6. Lorentz curve chart

According to Gini coefficient formula:

$$G = 1 - \sum_{i=1}^{n} (X_i - X_{i-1})(Y_i + Y_{i-1})$$

$$G = S_A / (S_A + S_B) = 1 - 2S_B = 2S_A$$

We got the global Gini coefficient G=0.44.

We substitute the calculated Gini coefficient into four membership functions, thus obtaining the membership degree of poverty gap to each comment in the comment set, which is denoted as

$$M1_{(3)} = [0, 0.3, 0.7, 0]$$

- Having solved the problem of the influence of poverty gap on global equity, we also want to discuss the influence of environmental resources on global equity. Under the primary factor environmental resources, we set two secondary factors , namely resource occupancy and allocation of mining resources.

Firstly, we think that resource occupancy is a factor to measure the richness of a country's resources. These resources are always destiny. Some countries are geographically superior and rich in resources, such as many countries in the Middle East and coastal countries. Resource richness is usually an objective reality, which is hard for us to influence. In order to determine the membership degree of this factor to each comment, we evaluate resource occupancy by analogy with Gini coefficient method, because we believe that the fairness of resource occupancy is closely related to the per capita possession of natural resources [3]. After analyzing and calculating the total population and resource coverage of those 12 countries, we got the membership degree of this factor to each comment in the comment set, which is recorded as

$$M2_{(1)} = [0, 0.2, 0.7, 0.1]$$

Secondly, we define the factor allocation of mining resources as the distribution of shared mining resources in the world. These resources do not belong to any country, but are the common property of all mankind, such as iceberg resources, fresh water resources, marine resources and outer space resources. Take asteroid resource as an example. This kind of space

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202301_6(1).0013

resource should shared by human beings and is a global property. Advanced countries can't get all mining rights. Even if some countries can't go to the outer space, they should have a share. Therefore, it is very important to distribute such resources fairly, which is related to global equity. As to how to distribute the global shared resources fairly, we will discuss it in the next part.

Given that it is difficult for us to define the evaluating standard of fairness concerning, we decided to adopt the scoring method, with the full score of 100 points, absolute fairness of 90 points, relative fairness of 70 points, relative unfairness of 30 points and unfairness of 10 points. We will collect information and data to give a fair and equitable score to the today's global resource allocation.

Let's write this factor's four membership functions:

$$R_{21}=\begin{cases}0 & , \quad x\leqslant 70,\\ \dfrac{x-70}{90-70} & , \ 70<x<90\\ 1 & , \quad x\geqslant 90\end{cases} \qquad R_{22}=\begin{cases}0 & , \quad x\leqslant 30,\\ \dfrac{x-30}{70-30} & , \ 30<x\leqslant 70,\\ \dfrac{90-x}{90-70} & , \ 70<x<90,\\ 0 & , \quad x\geqslant 90.\end{cases}$$

$$R_{23}=\begin{cases}0 & , \ x\leqslant 10,\\ \dfrac{x-10}{30-10} & , \ 10<x\leqslant 30,\\ \dfrac{70-x}{70-30} & , \ 30<x<70,\\ 0 & , \quad x\geqslant 70.\end{cases} \qquad R_{24}=\begin{cases}1 & , \quad x\leqslant 10,\\ \dfrac{30-x}{30-10} & , \ 10<x<30,\\ 0 & , \quad x\geqslant 30.\end{cases}$$

At present, the global awareness of fair distribution is still very weak. Most developed countries around the world by rely on advanced technology and developed industry to exploit the shared resources, believing that resources should be owned by whoever has the ability to exploit, regardless of global equity. We think that there are few resources in the world that have been fairly distributed, so we give a score of less than 10 points, and then the membership degree of this factor to each comment is recorded as

$$M2_{(2)}=[0,0,0,1]$$

3.4.2. Fill in the fuzzy comprehensive judgment matrix

After data collection and analysis, we determined the membership degree of all factors to each comment in the comment set, and finally got the fuzzy comprehensive judgment matrix of primary factors as follows:

$$M=\begin{pmatrix}0 & 0.599 & 0.401 & 0\\ 0 & 0.067 & 0.233 & 0.7\\ 0 & 0.7 & 0.3 & 0\\ 0 & 0.5 & 0.5 & 0\end{pmatrix}$$

3.5. Comprehensive Evaluation

The primary factors set U=[E,R,P,C] is comprehensively judged, and the weight A=[0.467, 0.161,0.277,0.095].

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202301_6(1).0013

$$B = A * M = [0 \quad 0.532 \quad 0.355 \quad 0.113]$$

This result means that the membership degrees to absolutely fair, relatively fair, relatively unfair and unfair are 0,0.532,3,555 and 0.113 respectively. Because membership degree to relatively fair is the largest, we can conclude that the whole world is relatively fair.

4. Analysis of asteroid Mining Industry

4.1. Industry Brief

There is an asteroid belt between the orbits of Jupiter and Mars. The asteroids in the asteroid belt are remnants when the solar system forms. These asteroids are rich in a variety of rare resources and have become inexhaustible reserves of minerals and elements [4]. With the development of modernization and the progress of science and technology, the earth's minerals and elements have been over-exploited. It can be expected that the gradual reduction of earth's resources will pose a threat to human survival in the future. Under such prediction, people focus on asteroids in outer space, and obtain resources from asteroids to sustain the long-term survival of human beings.

4.2. Vision for the future

4.2.1. SWOT analysis of asteroid mining industry [4]

In addition to asteroids, there are other galaxies in the universe with abundant and scarce resources that could also be exploited. However, the mining of asteroids is more valuable now and in the near future than any other galaxies.

Next, we will use SWOT model for further analysis of asteroid mining.

◆ Advantage

Asteroids are more valuable to mine than other galaxies. We discussed the following advantages of asteroid mining:

a. Temperature is more stable;
b. Abrasive dust is easier to control;
c. Gravity is small;

◆ Weakness

Considering the current level of science and technology and the existing resources of earth, we discussed the disadvantages of asteroids mining.

a. It would be expensive to transport asteroid resources back and forth, even more expensive than the economic benefits of mining them;
b. The technology is difficult, and asteroid mining requires a combination of high level science and technology;
c. Financial support is lacking, and the asteroid mining needs great investment.

◆ Opportunities

Taking into account the resources of the earth and outer space, we discussed the potential opportunities for asteroid mining:

a. Rich reserves of minerals and elements: asteroid mining could become a resource for human space voyages or space stations in the future；
b. The material basis of human’s migration into space

◆ Threat

After considering the feasibility of asteroid mining, we analyzed the threats brought by asteroid mining:

a. Creation of space junk;
b. A threat to earth's survival: mining asteroids could change the orbits of some asteroids and other galaxies;

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c. The autophagy of space: mining asteroids could affect unknown galaxies or unknown organisms; thus causing the change of space mechanism and the autophagy of space.

4.2.2. Development trend of asteroid mining

Considering the earth's resources, the development of science and technology, the survival of human offspring and other factors, we have made the following predictions about the development trend of asteroid mining:

In the near future, asteroid mining can gradually become a profitable and large-scale industry, which can provide material guarantee for the development of humans.

4.2.3 Future vision assumptions

We'll make assumptions about the future of asteroids from two terms: the macro level and the micro level.

◆ Macro level

In the future, asteroid mining has formed a complete system, which not only serves as a transit station for human navigation and provides resources for human navigation, but also solves the problem of long-term survival of humans. Human beings can not only maintain the earth's resources through asteroid resources, but also achieve planetary migration.

◆ Micro level

At the micro level, we mainly elaborate from four aspects: the system of exploitation, the level of science and technology, and the balanced development of human economy.

A. The system of exploitation

In this section, we divide the system into: the miners, the acquisition of funds, and the process of exploitation.

a. Miners

In addition to each national space agency, each country will have an asteroid mining enterprise, which will become the main miners, and the National Space Agency will participate in the way of auxiliary.

b. Access to financial funds

- International assistance: In the special case of asteroid mining, countries can submit applications to the International Mining Union for financial assistance.
- State support: Mining enterprises can apply to the state for the support of state funds, and allocate funds to mining enterprises after the examination and approval of the state.
- Enterprise investment: Mining enterprises can find interested enterprises to invest, or cooperate with other mining enterprises, so as to complete financing.

c. Crowdfunding: With the permission of the government, enterprises can raise funds from the people of the country. Enterprises get the support of funds, and the profits obtained by enterprises after mining will be returned to the people in a certain proportion to benefit the people, thus realizing the situation of multi-party cooperation and win-win.

d. The process of exploitation

Asteroid mining is divided into two stages.

The first stage is to send a spacecraft to a large asteroid and scout out the exact location of resources for the next stage of mining operations.

In the second stage, another spacecraft is launched for the practical mining operation.

B. Science and technology level

a. Communication technology

The future communication technology will realize the integration of wired and wireless, providing more accurate data for space exploration.

b. astronautical technology

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The future space technology will no longer be limited to rockets, but more will be spaceships, propellers and so on.

c. Mining technology

The mining technology will be greatly developed in the future. Deep-space mining techniques can not only extract resources, but also break them down.

C. The economy develops in a balanced way.

The development of asteroid mining will be one of the most profitable industries in the future. Economic development has always been the priority of global equity. Therefore, in order to achieve global equity, we expect that the benefits of asteroid mining will keep the economic growth rate of each country relatively stable.

4.3. Influencing factors of asteroid mining industry

- National policy
- Science and technology
- Utilization of outer space resources
- The depletion of the earth's resources
- Cooperation among miners
- The law

4.4. The impact on global equity

4.4.1. Definition of equitable allocation of asteroid resources

The development of countries in the world today is extremely uneven. For example, the United States, Canada, Russia and other developed countries have better economies and rich natural resources, thus developing rapidly. However, due to historical and regional reasons, the economic development of many backward countries is difficult or even stagnant. Some countries suffer from perennial famine and drought, and their people even cannot meet the basic need of food and clothing. If we want to achieve global equity, the development of the third world should be thought deeply.

Recent years have witnessed the heated discussion of asteroid mining, and many astronomers are optimistic about the future of asteroids because they contain many rare mineral resources. According to the Global Mining Development Report 2019, mining resources provided 22.7 billion tons of energy, metals and important non-metallic minerals in 2018, with a total output value of 5.9 trillion US dollars, equivalent to 6.9% of global GDP. It can be seen that the impact of mineral resources on the economy is very obvious. And the outer space asteroid has extremely rich mineral resources, such resources once be fully used by people, the value is inestimable. The outer Space Treaty, signed by the United Nations in 1967, defines space as the common territory of all mankind. This means that the resources of space should, in principle, be shared by the whole world. Even if a country lands firstly exploit it, that does not mean it has all the rights of mining. We believe that if people can make use of such precious resources and distribute them fairly, it will make a great contribution to the fair development of all countries and global equity.

So how do we define asteroid equity? We believe that fairness is not about equal distribution, but about allocating resources to achieve similar results. We set a similar result as national per capita GDP, and we believe that the distribution of resources should be aimed at making developed countries, middle class countries and backward countries get similar PER capita GDP, so as to achieve equitable global development. In other words, under the condition that a series of factors such as the level of scientific development, geographical conditions, educational conditions and so on remain unchanged, the backward countries should be given more mined mineral resources so that their per capita GDP does not differ from that of developed countries.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202301_6(1).0013

It's a very idealistic scenario, and it's our vision for the future of asteroid mining, which we hope will lead to a new phase in the process of global equity. The question of how the extracted resources should be distributed, and what percentage of the asteroid resources each country should own, is open to debate.

4.4.2. Analysis of impacts of asteroid mining on global equity

We believe that if asteroid resources are fairly distributed and used, the future of asteroid mining is promising and asteroid mining will play an important role in promoting global equity, contributing to the progress of backward countries and achieving equal development of all countries in the world.

Based on the assumption that the distribution of asteroid mineral resources will be completely fair in the future, we adjusted the membership degree of the factor to each comment in the comment set. The results are as follows:

$$M2_{(2)}' = [0 \quad 0.25 \quad 0.75 \quad 0]$$

Because the value of asteroid mineral resources is very high, the fairness has been greatly improved compared with before. Then, we further calculated the adjusted fuzzy comprehensive judgment matrix of primary index, which is recorded as

$$M' = \begin{pmatrix} 0 & 0.599 & 0.401 & 0 \\ 0 & 0.234 & 0.733 & 0.033 \\ 0 & 0.7 & 0.3 & 0 \\ 0 & 0.5 & 0.5 & 0.5 \end{pmatrix}$$

Finally, we conduct comprehensive evaluation again, and the result is

$$B' = A * M' = [0 \quad 0.559 \quad 0.436 \quad 0.005]$$

Compared with the previous results, the membership degree to relatively fair increases slightly, and the degree to unfair decreases significantly, so we can know that the fair distribution of asteroid mineral resources has a positive impact on the realization of global equity.

4.5. Correlation Analysis

In the previous part, we pointed out that the future of asteroid mining industry is influenced by many factors such as policy support, financial fund, mining technology and awareness of resource equity, and the global equity is closely related to these factors. These factors plays different roles in global equity. Therefore, we decided to use grey relational analysis to explore how changes in asteroid mining industry affect global equity.

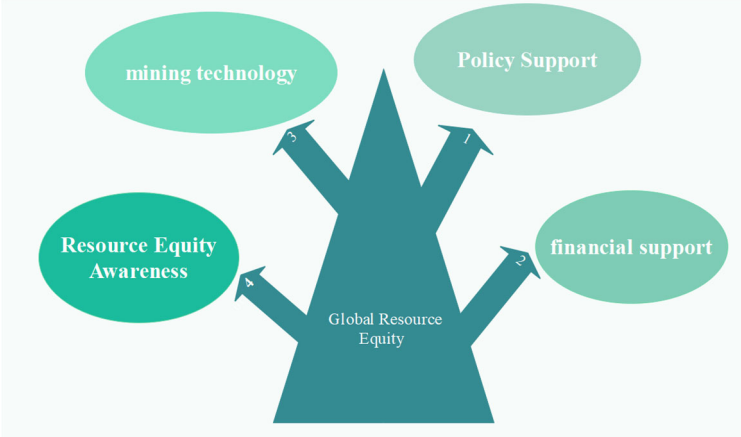

Figure 7. The framework of influential factors

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- Determining the comparison sequence and the reference sequence

In order to analyze an abstract system, we should firstly select the data series that reflect the behavior characteristics of the system, and use the mapping quantity to indirectly represent the behavior. For example, we can use the global equity index to reflect the degree of equity, the number of policies on asteroid exploitation to reflect the policy support, and the number of published scientific journals to reflect the level of technology.

In the system we want to evaluate, we determine the global equity as the reference sequence, which is recorded as: X_0. The policy support, financial support, the level of technology and the awareness of fairness are identified as comparison subsequences, which are respectively recorded as X_1, X_2, X_3, X_4.

- Preprocessing variables

In order to eliminate the influence of dimensions and simplify the calculation, we need to preprocess the data of five factors, which means to find out the mean value of each factor' data first, and then divide each element by its mean value.

$$X_0 = (X_{0^{(1)}}, X_{0^{(2)}}, X_{0^{(3)}}, \cdots X_{0^{(n)}})^T \quad \rightarrow \quad \text{reference sequence}$$

$$\left.\begin{aligned} X_1 &= (X_{1^{(1)}}, X_{1^{(2)}}, X_{1^{(3)}}, \cdots X_{1^{(n)}})^T \\ X_2 &= (X_{2^{(1)}}, X_{2^{(2)}}, X_{2^{(3)}}, \cdots X_{2^{(n)}})^T \\ X_3 &= (X_{3^{(1)}}, X_{3^{(2)}}, X_{3^{(3)}}, \cdots X_{3^{(n)}})^T \\ X_4 &= (X_{4^{(1)}}, X_{4^{(2)}}, X_{4^{(3)}}, \cdots X_{4^{(n)}})^T \end{aligned}\right\} \rightarrow \quad \text{comparison sequence}$$

- Calculate the correlation coefficient

We define: $a = \min_i \min_k |X_o(k) - X_i(k)|$

$$b = \max_i \max_k |X_o(k) - X_i(k)|$$

$$y(X_{0^{(k)}}, X_{i^{(k)}}) = \frac{a + \rho b}{|X_o(k) - X_i(k)| + \rho b}$$

$$y(X_0, X_i) = \frac{1}{n} \sum_{k=1}^{n} y(X_{0^{(k)}}, X_{i^{(k)}})$$

$y(X_0, X_i)$ is the grey correlation degree of X_0 and X_i. So, we can get all the correlation coefficient between X_0 and X_1, X_2, X_3, X_4 respectively.

- Evaluation and analysis

According to the grey correlation analysis, we can know the correlation between the global equity and the four factors: policy support, financial support, mining technology and awareness of fairness. The greater the correlation degree, the greater the influence of the factor on global equity. The results are beneficial for people to formulate strategies to promote the development of global equity.

5. Policies That Promote Global Equity --- Asteroid Mining

5.1. Policy Overview

In order to promote global equity and fair distributions of untapped resources, we discussed policies that intend to make asteroid mining industry develop healthier. The policies include:

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resource ledger policy, international tax policy, and bonus policy. We will carry out a specific analysis of each policy below.

5.2. Specific policy analysis

Resource ledger policy [6]

Let's briefly talk about the meaning of the resource account book: that means the government can set up a natural resource account for everyone, distribute the average share of natural resource consumption to everyone according to the real-time economic value, and release the prices of all products that depend on the natural resource account and operate according to the laws of market economy. This policy can fully embody the equity

Next, we will explain the rationality of this policy in detail. The reasons will be shown as follows:

Firstly, everyone has the right to survive in the world, and people depend on natural resources to live. Natural resources should belong to everyone equally, and can't be occupied only by someone, a group or even a country.

Secondly, Natural resources has its own value, and this value can be calculated at some time. Everyone should have his own share of natural resource property, so this natural resource property has the right to be guaranteed and protected.

Under the resource ledger policy, the public is more willing to support the asteroid mining business of mining enterprises, and can also provide a lot of information and support for mining enterprises, which not only benefits the public, but also encourages mining enterprises to further mine, and ultimately achieves global equity.

International Tax Policy [7]

International institution must comprehensively consider the situation of mining enterprises, their financial ability, the awareness of fair cooperation of mining enterprises and the credit of mining enterprise managers, and then establishes a database for each mining enterprise. In this database, there are various information of enterprises, and the best tax rate is obtained by weighting the weights of each factor after mining and making profits, and the mining enterprises should pay taxes to international institutions.

Next, we will elaborate on the applicability of the policy. We will explain from these following points:

Firstly, the international institution establishes an information database for each enterprise. After the international institution sets the weight of each factor, artificial intelligence will extract data from the database and calculates the data to get the best tax rate as the tax rate paid by the mining enterprise. Considering all factors comprehensively, it will not be too subjective, but also promote the benign development of mining enterprises and benefit all mankind.

Secondly, the concept of fair cooperation in international tax policy refers to cooperation between mining enterprises (same or different countries), mining enterprises help developing countries with their profit donation, etc. In these cases, the tax rate will be reduced accordingly.

Thirdly, another benefit of international tax policy is that some of the international revenue from tax policy can be got and some of it can continue to be used to fund the research of asteroid mining. Part of the storage can be allocated to the disaster area in time to help the disaster area recover in time.

Bonus policy

Bonus policy, colloquially speaking, means that mining enterprises will use the benefits obtained by mining asteroids to promote the global equity, and the international organization will give corresponding awards.

Next, we will explain the bonus policy in detail.

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Firstly, the primary purpose of the additional award policy remains to promote global equity, benefit all mankind and seek the well-being of all mankind. In the form of awards, the mining enterprises are encouraged to attach importance to global equity and cultivate the cooperative consciousness of mining enterprises, so as to truly achieve global equity.

Secondly, the bonus policy not only benefits mining enterprises, but also help the disadvantaged groups to enjoy the resources fairer.

We show the above three policies with simple graphs, as shown in the following figure:

Figure 8. Policy diagram

6. Strength and Weakness

6.1. Strength

✓ When evaluating global equity, we considered 4 primary factors and 9 secondary factors which made our model more comprehensive and objective.

✓ When we do K-means++ clustering, we considered nearly many sets of data from 98 countries. These indicators help us better divide countries, making our research more reliable.

✓ We use FCM to measure the global equity system, dealing with the fuzzy evaluation objects by precise numerical means, so that we can make a scientific, reasonable and realistic quantitative evaluation of the information with fuzzy information.

✓ When analyzing the correlation degree between global equity and various factors, we use the grey correlation analysis method, which can make up for the lack of data, with less calculation and no discrepancy between quantitative results and qualitative analysis results.

6.2. Weakness

➢ Because the data is difficult to collect, we can't use Entropy Weight Method (EWM) to determine the weight. The Analytic Hierarchy Process (AHP) we adopted is greatly influenced by subjectivity. Although we refer to some material, the weight of our factors is still subjective.

➢ K++-means clustering algorithm requires users to give the number K of clusters in advance, so the classification always depends on the experience and feeling of person.

➢ Because asteroid mining industry is still immature, we can only find little data, and there are many unknown factors in asteroid mining, so we can't accurately predict the future trend of asteroids.

➢ In grey relational analysis, it is difficult to find a mapping quantity to quantify the abstract concept of fairness.

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6.3. Future Discussion

By studying relevant materials, we find that global equity is influenced by multiple factors, If time is permitted, we will consider more factors including science, technology and capital expansion to measure global equity better.

In the future, we will consult some experts, collect more data concerning asteroid mining, and build a database to be dedicated to asteroid mining industry, making human beings achieve greater development.

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