Problem Chosen	2022 MCM/ICM Summary Sheet	Team Control Number
F		2225122

Global Equity: Let the countries appear "spindle" distribution

Summary

With the development of society, asteroid mining, as one of the most direct ways to increase earth resources, has been paid more and more attention by many countries.

In response to the first question, as asteroid mining is a brand-new industry, we first developed a model to define global equity. We define the **equity ratio E** as the ratio of input to the output of each country, but it is different from the contribution rate. The equity ratio measures the similarity of the output of each country and is the unit output. Global equity is determined by the number of countries that are close to the overall average. The more number, the better.

Subsequently, we formulated three indicators: **input**, **benefit**, and **harm**. The reasons for choosing these three indicators are as follows: fairness mainly focuses on output, but input will affect output, and not all outputs are positive, so we choose hazard indicators as a measure of total output. Then, we set up the **IBH(Input-Benefit-Harm)** model, used the **Entropy Weight** method to give weights to the indicators, calculated the equity ratio of 11 selected countries, and classified these 11 countries according to the **K-means Clustering** method. Then we find that the distribution of countries shows a shape of "hourglass", that is, the national equity ratio deviated from the overall average. To verify our model, we evaluate India from two dimensions: **history (vertical)** and **region (horizontal)**.

In response to the second question, we described the blueprint of asteroid mining. Our description is divided into three parts: the mining industry, the mining methods and the benefit. We use **Pearson Correlation Coefficient Matrix** to get the relationship between input indicators, and use **Multiple Linear Regression** to get the influence of input on benefit. Finally, based on the idea of the **Game Theory**, we analyze the impact of the vision on global equity. We find that both kinds of countries choose to increase investment.

As for the third question, aiming at the fair distribution of mineral resources proposed in the vision (70% of mineral resources are shared by mining countries and 30% by non-mining countries), we use the **Dynamic Programming Algorithm** to calculate the optimal change rate, and bring it into IBH model to analyze the impact on global equity. Then, we set the equal distribution (two kinds of countries share minerals equally) and compare it with the fair distribution in the vision, and finally draw the conclusion that fair distribution will increase the mean value of the equity ratio.

In response to question 4, in order to promote more global equity, we put forward corresponding policies according to the analysis of the mechanism of the impact of input indicators on the equity ratio in question 3. Finally, the distribution of equity ratio is **spindle-shaped**, that is, more countries' equity ratio are concentrated on the overall average. At last, we **analyze the sensitivity** of negative externality coefficient alpha, and finally get the alpha value can most directly affect the overall level of equity ratio while having some effect on its distribution, but not enough to change the results of clustering.

Keywords: Entropy Weight; K-means Clustering; Pearson Correlation Coefficient Matrix; Multiple Linear Regression; Game Theory; Dynamic Programming Algorithm

Contents

1 Introduction

1.1 Background

Most countries in the world agreed in the UN Outer Space Treaty signed in 1967 that the exploration and utilization of outer space should promote the welfare and interests of all countries[1]. That is to say, every country has a fair right to explore outer space. With the progress and development of human society, every country is seeking more resources. When "planetary mining" becomes a reality and is beneficial to national development, we need to find a fairer way to distribute resources and opportunities to achieve global equity.

1.2 Problem Restatement

We need to:

1. Define global equity and develop a model that can measure global equity.

2. Propose, describe and demonstrate a possible future of asteroid mining, and determine the impact of mining on global interests through analysis.

3. Analyze the impact of changes in the asteroid mining industry on global equity.

4. Put forward reasonable policy, so that asteroid mining can really benefit mankind.

1.3 Our Work

1. According to the definition of fairness, we define global equity as the similarity of national output. For the principle of "more work and more gains", the concept of the equity ratio is used to express the unit output, so as to measure whether the output is similar.

2. The **IBH (input-benefit-harm) Model** is established, which includes five input indicators, three benefit indicators and one harm indicator. After standardizing the data, the **Entropy Method** is used to weight these indicators in input and output levels. Finally, the equity ratio is calculated, and it is found that the selected 11 countries are "hourglass", far from the global equity. India was chosen to compare with the world average **horizontally** and **vertically**.

3. In the defined asteroid mining vision, the relationship between the input index and the benefit index is obtained by using **Multiple Linear Regression** analysis for standardized data, and the changing trend of the input index is determined by combining with the **Game Theory** and other methods. Then, using the algorithm of the **Dynamic Programming**, the optimal change rate of non-mining countries and mining countries after ten years is obtained. Finally, it is found that the average level of global equity has improved and the distribution is spindle-shaped.

4. In order to reach the situation described in question 3, based on the existing Outer

Space Treaty and other documents, we put forward new principles that are conducive to the input index to become within a reasonable range, and policy suggestions extended from these principles.

2 Assumptions

1. **All countries involved in the article conform to the hypothesis of economic man.** That is, the decisions made by all countries are absolutely rational, and all countries pursue the maximization of interests.

2. **All the data are accurate and reliable.** Our data come from the Worldbank[2] and EPSDATA[3]. In this article, we will not discuss the authenticity of the data.

3. **In a short time, there are unlimited resources available for exploitation on asteroids.** Human beings have not proved the existence of intelligent alien creatures, so under the concept of human time, resources on asteroids have never been developed and utilized before. In a short time, the resources on asteroids can be exploited and utilized indefinitely by human beings.

3 Notations

The main notations are shown in Table 1

Symbol	Definition
f_{ij}	The i-th country's j-th benefits
x_{ik}	The i-th country's k-th input
w_j	The weight of each index
h_i	The harm of the i-th country
E_i	The equity ratio
zij	f_{ij}, x_{ik}after standardization (z-score)

Table 1: Notations

4 IBH (Input-Benefit-Harm) Model reflects global equity

In the process of measuring global equity, we first define global equity: global equity refers to taking each country as a whole, measuring each country's allocation of resources and opportunities, and obtaining similar output.

Secondly, according to the United Nations Charter and [4][5], we formulate four

principles to measure fairness: the principle of fairness per capita, the principle of historical responsibility, the principle of the ability to pay, and the principle of future development opportunities. In order to measure equity, we define the Equity Ratio. Subsequently, we have defined three indicators according to four principles: input, benefit and harm (They are collectively called outputs). And we determined specific indicators according to the website World Bank[2] and EPSDATA [3]. Then, we evaluate the related indexes of input and output. We assign weights to the indicators, and the weights are determined by the entropy weight method based on data. We use the K-means clustering method to classify the Equity Ratio, compare the equity ratio of each country with the average value global. Then, we get the differential value and use the differential value to measure fairness. Finally, we verify our model through historical data and regional data, that is, vertical and horizontal dimensions.

4.1 A definition about global equity

First of all, we define global equity: global equity refers to taking each country as a whole, measuring each country's allocation of resources and opportunities, and obtaining similar output. We choose the country as the smallest unit of measurement based on two principles: the principle of convenience and the principle of accuracy. It is relatively convenient to collect, process, and evaluate data by country, and the amount of data is less than that of smaller administrative units, which is convenient for comparative statistics, so the principle of convenience is followed. Compared with larger economies, such as the European Union, taking the country as the unit can measure fairness more accurately, so it follows the principle of accuracy.

To sum up, we propose our way to measure equity: we define the Equity Ratio, which is the ratio of national input and output. Each country has its own equity rate, which reflects whether countries have similar output. It is worth emphasizing that the equity rate is not a measure of efficiency, but the measurement of output.

4.2 IBH (Input-Benefit-Harm) model reflects the world equity

4.2.1 Principles for establishing indicators

First of all, in order to determine the global measurement, we formulate four principles of measuring equity according to the UN Charter and [4]: the principle of fairness per capita, the historical responsibility, the ability to pay, and the future development opportunities.

- **Per capita fairness** According to this principle, no matter in the past or in the future, every citizen on earth now enjoys the same rights to the resources, national welfare, and services in various fields on earth. Because this principle is too biased towards the input of resources, we only apply this principle to deal with different data of countries. In that way, different countries with different sizes can compare.

- **Historical responsibility** According to this principle, when people have positive or negative externalities to the outside world, they should consider the influence on the younger generation.
- **Ability to pay** This principle holds that the higher the income, the higher the corresponding cost, and the lower the income, the smaller the cost. Some countries below the threshold should not bear the payment cost, which will help to maximize the welfare of the whole world.
- **Future development opportunity** This principle holds that developed countries should give economic opportunities for developing countries or poor countries.

4.2.2 Main Factors of Global Equity

Then, we define three indicators according to four principles: input, benefit and harm for level 1, and in level 2, we have defined 13 factors, of which 5 are about input, 7 are about output and 1 is about harm(the specific indicators are in table 2). The data are all from World Bank[2] and EPSDATA[3]standards.

As for the reasons for establishing these three indicators, first of all, based on the definition of topic equity, we use factors that can affect input and output. However, because not all outputs are positive, and some environmental pollution will bring negative outputs, we further enrich the output indicators, and jointly define the harm index and the benefit index as outputs.

In need of special note is that the purpose of our definition of "input" is not to take inputs as the final measure, but to measure the final equity through the relationship between inputs and outputs. We use both benefit and harm to measure equity.

Indicators	Specific index	Code
Input	Total public expenditure on education, total (%of GDP%)	x_1
	Energy consumption of fossil fuels (%of total)	x_2
	Renewable inland freshwater resources per capita (cubic meter)	x_3
	Adjusted savings: loss of mineral resources (GNI%)	x_4
	Nuclear power generation (%of total power generation)	x_5
Benefit	Enrolment rate, institutions of higher learning (%of the total number)	f_1
	Per capita gross national income (GNI) measured by purchasing power parity (PPP) (current international dollars)	f_2
	High-tech export (%of manufactured goods export)	f_3
Harm	Per capita carbon dioxide emissions (tons)	h

Table 2: Indicators that affect equity

4.2.3 Create IBH(Input-Benefit-Output)Model

The selected indicators can be divided into input and output, in which the output includes benefit and harm.

- **Step1: Adopt a Z-score for standardization.** The purpose of this step is not only to make the index convenient for subsequent calculation but also to make different indexes comparable. In order to ensure that the standardized result is positive, we move it right by three units:

$$zij = \frac{oij - \bar{o}j}{\sqrt{\frac{\sum_{j=1}^{m}(oij-\bar{o}j)^2}{m}}} \tag{1}$$

Among them,$E_i$represents the original value of the j-th input or output index of the i-th country. (i=1,2...11, j=1,2...m,

$$m = \begin{cases} 5\text{...for input index} \\ 4\text{...for output index} \end{cases}$$

- **Step2:Calculate the entropy** We calculate the entropy value of each index according to the standardized index value.

$$ej = -\frac{1}{\ln n}\sum_{i=1}^{n} zij \times \ln zij \tag{2}$$

Where n represents the number of samples, and we selected 11 countries, then n=11.

- **Step3: Calculate the weight of each index**

$$wj = \frac{1-ej}{\sum_{k=1}^{m}(1-ek)} \tag{3}$$

Particularly, w^{in},w^b,w^h represents the weights of input, benefit and harm respectively.

- **Step 4: Calculate the equity ratio** We letf_{ij},x_{ik} represent the i-th country's j-th benefits and the i-th country's k-th input. $h_i$represents the harm of the i-th country, then the equity ratio $E_i$of the i-th country can be expressed as:

$$Ei = \frac{(\sum_{j=1}^{3} w_j^b \times fij - \alpha w^h \times hi)^{1/4}}{\sum_{k=1}^{5} w_k^{in} \times xik)^{1/5}} \tag{4}$$

α means that considering the negative externalities of environmental pollution, the harm to the country is less than its actual harm to the international community, so the value of $\alpha$is less than 1, and here α=50It's worth noting that we don't consider externalities by analogy, which is based on the assumption that all individuals are rational economic men, pursuing the maximization of interests, obtaining all the benefits and reducing the harm of income.

4.3 Measure equity

We selected 11 countries including Japan, South Korea, China, Switzerland, the Czech Republic, Russia, Ukraine, India, Pakistan, the United States, and Canada, and classified the fair rate by the K-Means method according to the data of 2019. We assume that indicators with no data in that year are the same as the last statistics. As we mentioned above, the equity rate we defined is the ratio of input to output. We compare the equity rate of each country with the global average. The closer the equity rate of a country is to world average, the fairer it is compared with other countries. Figure 3 is a cluster analysis diagram.

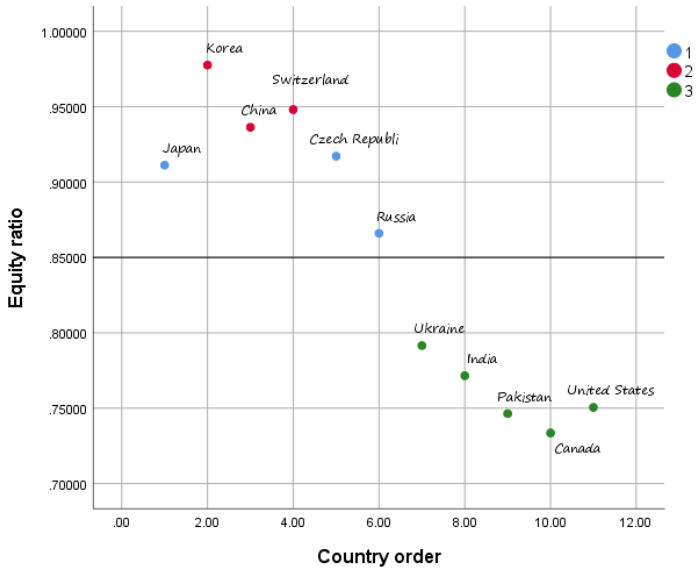

Figure 1: Classify the equity rate by K-means

According to the cluster map, eleven countries are divided into three groups according to the degree of difference with the world average. Japan, the Czech Republic, and Russia are the first group, South Korea, China, and Switzerland are the second group. Ukraine, India, Pakistan, the United States, and Canada are the third group. It can be seen that countries in group 1 are closer to the world average and fairer than other groups of countries. However, the second group of countries has a high equity rate, while the third group of countries has a low equity rate, which makes both groups of countries have high room for improvement.

4.4 Verify the model with history and region

In order to verify the model, we selected India as the country to carry out the historical and regional level, that is, two-dimensional angle verification based on horizontal and vertical levels.

- **Historical level**

According to Figure 4, from the comparison chart of the average annual equity rate between India and the world, we find that the equity rate in India is increasing year by year, but it still does not reach the average level of the selected countries over the years. It can be seen that the equity rate in India needs to be improved.

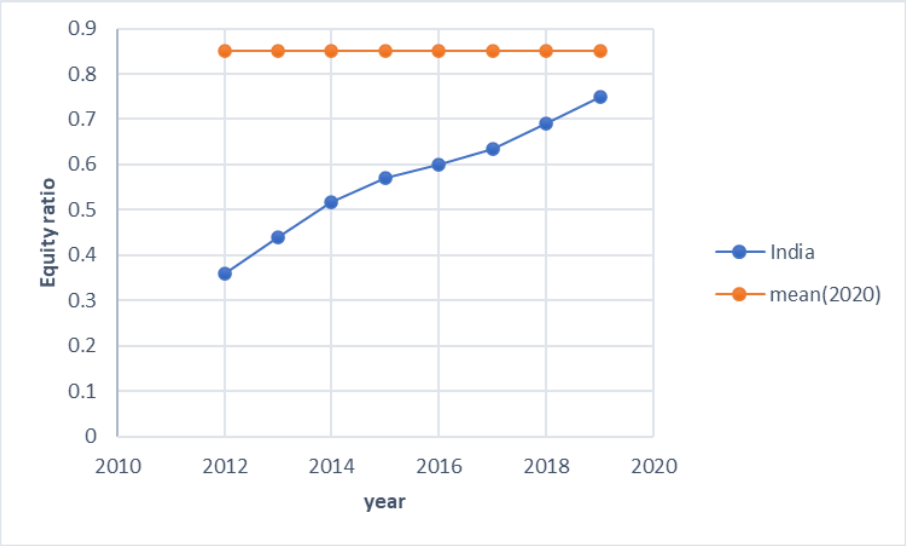

Figure 2: Equity ratio of India and the mean value of world

- **Regional level**
  According to Figure 3, we can see that India is in the third group of countries, and the third group of countries is characterized by low equity rate. At the same time, in different countries (different regions), the equity rate in India is lower than that in other countries, which shows that the equity rate in India needs to be improved from the horizontal dimension. All our descriptions of fair rate above have been verified.

  Then, we use the average data of global to compare with India (Figure 5), and find that the world average is lower than India. Before, India was at a low level of equity rate among the selected countries, while the world average was even lower, which shows that there are still many countries in a state of extreme unfairness. At the same time, India's growth tends to be flat, while the world average shows exponential growth, which can explain that the equity situation has slowed down in recent years.

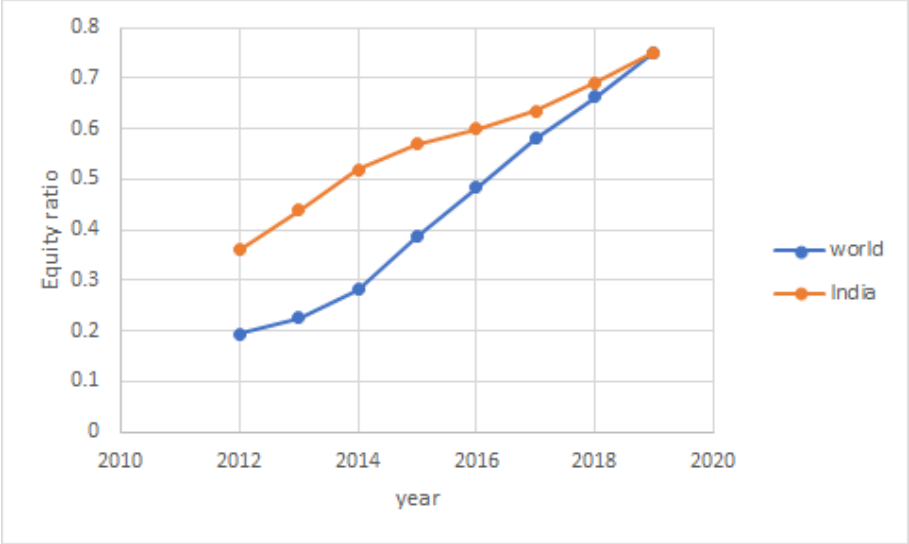

Figure 3: Average data of global and India

5 Blueprint for asteroid mining

In this problem (Task 2), we describe the future condition of asteroid mining base on [6]. And our description can be divided in to 3 parts: mining industry, mining methods and profit making. In view of the impact of asteroid mining on global equity, we mainly consider the impact of mining on the three indicators we selected above. First of all, the indicators directly affected by asteroid mining are hazard and investment. We analyzed the impacts of asteroid mining on each of the above two indicators. At the same time, the investment will affect the benefit. We use the method of multiple regression to analyze the correlation degree between the input index and the benefit index. Finally, we get the impact of asteroid mining on global equity.

5.1 The future of asteroid mining

So far, the earth's inner mineral resources have been exhausted due to excessive exploitation. With the increasing development of space technology, asteroid mining will become feasible. In accordance with the future of asteroid mining, we first propose the following hypotheses:

- Planetary mining technology is both feasible and profitable.
- The benefits of private mining are taken into account along with the host country.
- Equity in asteroid mining is measured in terms of distribution and similar outcomes.
- Since cooperation between countries is not compulsory, cooperation depends on the game between countries.

5.1.1 Future of mining industry

The United States, Japan, China and Luxembourg are currently conducting asteroid mining research, so it will mainly launched in these four countries. The asteroid mining industry in these four countries is relatively mature. They have relevant technology, well-trained space miners, sophisticated workflow and a relatively complete industrial chain. They are responsible for mining, trading and selling.

The rest of the world's unskilled countries, as purchasers of minerals, conduct transactions in accordance with the well-established trading laws and processes.

The world mining industry will present a new state, and the energy consumption and supply pattern will change. In addition to the power system, hydrological systems, the asteroid mineral system will also become monopolized industry.

It is particularly important to emphasize that as for the **distribution** of minerals, the mining countries and non-mining countries will sign a treaty to fix the distribution ratio of minerals in the future. The mining countries will get 70% of the minerals and non-mining countries will get 30% of the minerals. This distribution method will be **verified** later, and our verification shows that this ratio will improve **global equity**.

5.1.2 Future of mining methods

Since we previously assumed that the mining technology is feasible, the mining methods in this section focus primarily on the arrangement of personnel. In the future, mining personnel are mainly composed of compound talents who have received astronaut training and have been engaged in mining industry research. The reason why we set it this way is that despite the technical support in the future, space work is always a hazardous work, and we need talents with both physical fitness and knowledge. We assume that the country's education keeps developing, so more and more high-tech talents will emerge in the future.

At the same time, countries will set up workstations on asteroids with resident technicians to keep the workstations running. The daily life of the space miners and technicians is completed in the workstation, and they have signed a perfect working agreement.

5.1.3 Future of profit making

When mined, the minerals are eventually traded on the market. The profits can be divided into two categories: mining country and purchasing country.

The first case is that as a mining country, the minerals mined from the asteroid can not only be used as alternative energy in its own country, but also can be sold to other countries, which helps it not only saves the use of resources, but also obtains some benefits. Similar to today's relationship between oil producing countries, the mineral producing countries of the planets would be constrained by each other, so they would unite as a planetary cartel.

The second case is that as the purchasing country, although they cannot benefit directly from the exploitation of mineral resources, the mineral bought from mining countries can replace the existing resources. To a certain extent, it alleviates the energy shortage and promotes the long-term benefits of the country.

5.2 Impact of asteroid mining on global equity

5.2.1 Influence of asteroid mining on harm index

Asteroid mining will have a direct impact on hazard indicators. The index that measures the harm is h(per capita carbon dioxide emissions (tons)). Asteroid mining will bring more mineral resources to mankind. With the increase of carbon dioxide emissions, pollution will become more serious.

5.2.2 Influence of asteroid mining on input index

Asteroid mining will also have an impact on input indicators.

- **The influence of x_1**

  We believe that the investment in education will not change for countries that have mastered mining technology. Countries that have not yet mastered the technology want to join the mining industry, so they will increase investment in education and train more high-tech talents.

- **The influence of x_2**

  As we know, the main resources on asteroids are carbonaceous resources, siliceous resources, and metallic resources [6], so when human beings exploit the mineral resources on asteroids and put the minerals into use, the fossil energy consumption on earth will be reduced. Therefore, asteroid mining has a negative correlation with this index.

- **The influences of x_4**

  When human beings exploit the mineral resources on asteroids and put the minerals into use, they will reduce the loss of mineral resources on the earth. Therefore, asteroid mining has a negative correlation with this index.

- **The influences of x_5**

  Asteroids are rich in hydrogen isotopes such as H^1,H^2,H^3[6], and hydrogen play a vital role in the development of nuclear weapons. Therefore, asteroid mining has a positive correlation with the development of nuclear energy. We use the Pearson correlation matrix to analyze the correlation of five indicators at the input level, and find that x_2 is extremely negatively correlated with x_5, which also confirms our assumption.

5.2.3 Influence of asteroid mining on equity

Asteroid mining directly affects the input index, while the input index directly affects the benefit index, so mining can indirectly affect the benefit. We use Multiple Regression to analyze the correlation degree between the input and the benefit. The results are as follows (because the analysis process of each index is the same, we only use f_1 as an example to describe the process, while we only show the results of $f_2$and f_3)

```
. regress f1 x1 x2 x3 x4 x5
note: x5 omitted because of collinearity.
```

Source	SS	df	MS	Number of obs	=	8
				F(4, 3)	=	8.17
Model	7.3271351	4	1.83178378	Prob > F	=	0.0579
Residual	.672864898	3	.224288299	R-squared	=	0.9159
				Adj R-squared	=	0.8037
Total	8	7	1.14285714	Root MSE	=	.47359

f1	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
x1	.0919178	.2169065	0.42	0.700	-.5983754	.782211
x2	.4872601	.450906	1.08	0.359	-.9477242	1.922244
x3	-.6106345	.3491191	-1.75	0.179	-1.721687	.5004182
x4	.1167779	.2663701	0.44	0.691	-.7309305	.9644863
x5	0	(omitted)				
_cons	2.744036	3.195438	0.86	0.454	-7.425272	12.91334

Figure 4: Multiple Regression of f_1

It can be seen from the figure that our estimated regression equation is:

$$\hat{y} = 2.744036 + 0.0919178x_1 + 0.4872601x_2 - 0.6106345x_3 + 0.1167779x_4 \quad (5)$$

The coefficient R-Square=91.59As the same, the coefficient of R-squared for$f_2$and$f_3$is 93.02% and 89.25%, respectively, which shows that the regression equation has a high degree of fitting. The following three pictures show the fitting curve of the three indicators respectively.

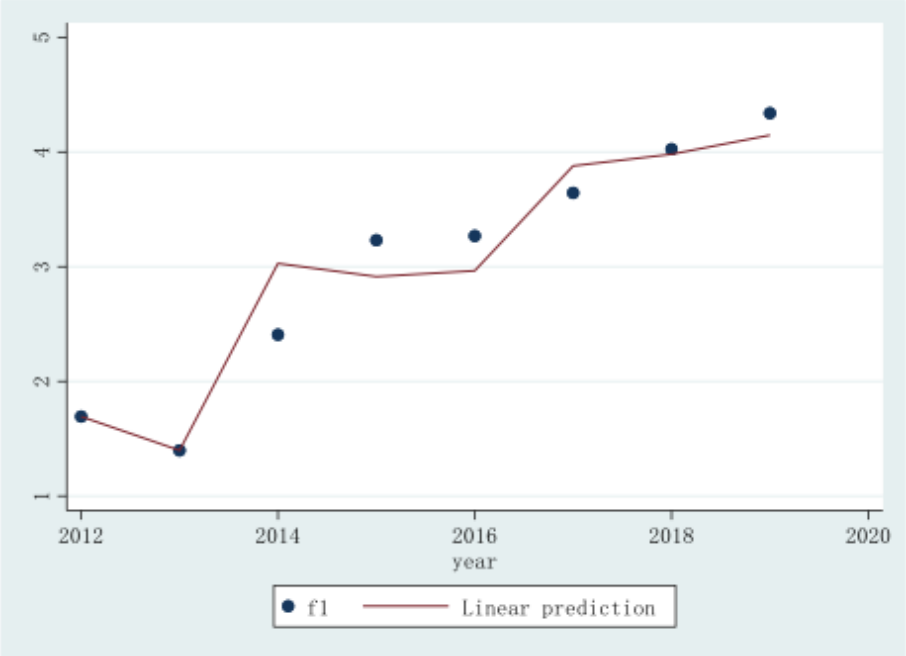

Figure 5: The fitting curve f_1

5.2.4 The game between exploiting and non-exploiting countries

In this section, we use the idea of Game Theory to analyze the choice of input between the mining countries and the non-mining countries. We assume the mining country as T and the non-mining country as F. Numbers in the table following the ordinal number theory, and the size of numbers only represents the degree of choice. The larger the number, the better the choice.

Through the table above, if mining countries choose to increase investment, non-mining countries will also increase investment to catch up with mining countries. If mining countries do not increase investment, non-mining countries will take the opportunity to increase investment to narrow the gap with mining countries; if non-mining countries choose to increase investment, mining countries will also increase investment in order to continuously guarantee their position; if non-mining countries choose not to increase investment, mining countries will still increase investment to consolidate their monopoly position.

F \ T	Increase input	Constant input
Increase input	(6,2)	(4.1)
Constant input	(5,1)	(3,0)

Figure 6: The game table

Therefore, the best choice for both countries is to increase investment. Increasing

investment will be the world trend of the asteroid mining industry in the future.

6 The influence of vision on global equity based on Dynamic Programming model

In the fifth part, we draw a conclusion based on the game theory: in the future planetary mining industry, both mining and non-mining countries will choose to increase investment. We assume that the distribution methods are different, and it is an important part in this section to get the influence of different distribution methods on global equity.

We defined two ways of equality and equity. Our goal is to find a fairer way in these two ways, that is, after clustering analysis, the more countries are closer to the mean value, the max the mean value, the better. We use the Dynamic Programming model to analyze the two ways.

6.1 Equality and equity distribution

Equality refers to complete equality, that is, mining countries give half of the minerals they get to non-mining countries in various ways. Equity refers to the mining countries will keep 70% of all minerals and the remaining 30% will give to non-mining countries in various ways according to the principle of "more for more work".

6.2 Dynamic Programming analysis

Based on our goal, the number of countries clustered in the middle should be as large as possible:

$$\max num, \bar{E}$$
$$s.t. \begin{cases} x_{ij}(t+1) = x_{ij}(t) \cdot (1+\beta_j^{T/F}) \\ h_j(t+1) = h_j(t) \cdot (1+\beta_h^{T/F}) \end{cases}$$

where β is the rate of change. The table about the changing rate and other index shows in table.This table describes the rate of change of each index:

	$\beta^T(\%)$	$\beta^F(\%)$
h	[0.05,0.25]	[0.1,0.5]
x_1	[0.1,0.5]	[0.2,1]
x_2	[0.2,1]	[0.1,0.5]
x_4	[0.05,0.25]	[0.1,0.5]

It can be seen from the table that the change rate of x_1 and x_2 in the mining countries is relatively large; among the non-mining countries, the change rate of x_1 is larger.

Our final result is shown in the figure 7.

Figure 7: Dynamic Programming analysis result

From the pictures, we can see that the average value of the fair rate based on fair distribution is higher. After the cluster analysis, more countries are close to the average value, and the distribution of countries around the world on the cluster map is closer to ”spindle shape”. This shows that under the premise of our proposed vision, the asteroid mining industry will develop towards a fairer trend in the future.

7 Putting forward the policy

Our updates to the Outer Space Treaty mainly include further defining the nature of outer space resources, namely asteroids and their appendages, and introducing new principles. Based on the principles of the updated Outer Space Treaty, combined with the results of our analysis, this paper puts forward policy recommendations that are conducive to promoting global equity. In our model, even if it is embodied in the policy of making the fair rate of most countries close to the global average.

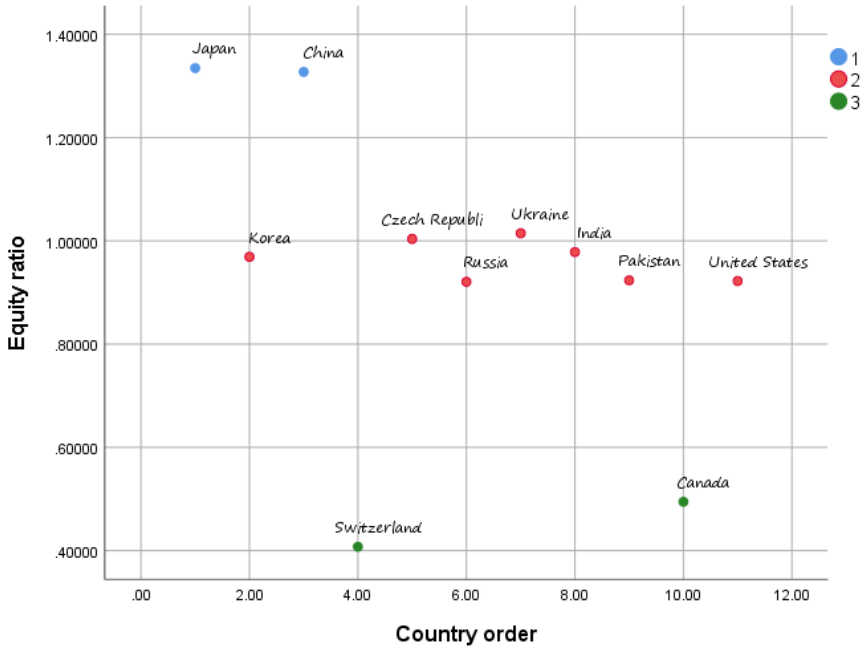

Figure 8: The lated K-means result

We have made two updates to the content of the Outer Space Treaty:

1.temporarily define asteroids and their resources as ”common property”, that is, the sovereignty of asteroids belongs to all countries, but the mineral resources as attachments of asteroids can obtain ownership through conventional development means. Here, we have not applied the definition of ”the common heritage property of mankind” adopted by some international treaties such as the United Nations Convention on the Law of the Sea and the Moon Agreement to the Outer Space Treaty [7], because the requirement of benefit-sharing in this definition, that is, sharing the ownership of the mined objects, will inhibit the enthusiasm of the mining countries for mining. If China reduces or even does not exploit, the asteroid mining will inevitably fail to promote the fair development of the world.

2.We introduce the principle of ”paying special attention to the interests of developing countries” [8], and the developing countries mentioned in the principle refer to countries that do not have the technology to exploit asteroids. The purpose of introducing this principle is to restrict the exclusive exploitation of resources by the mining countries. For example, in education, energy and other industries, the mining countries transfer part of the profits gained through mining to non-mining countries.

Our proposed policies are as follows:

1.Non-mining countries increase their investment in public expenditure on education while developing GDP, and increase the proportion of total public expenditure on education to GDP. The United Nations should focus on non-mining countries in the global education fund support, so that the proportion of non-mining countries in the increase of education investment is more than that of mining countries.

2.The research of high-tech depends on the development of higher education, and the development of higher education has a great influence on the expenditure of education. The United Nations encourages mining countries to organize asteroid mining technology exchanges, and provide relevant technical personnel to non-mining countries, so as to promote the sharing of mining-related high-tech among countries around the world.

3.For the non-mining countries with nuclear power generation, when mining the nuclear power generation raw materials such as helium 3, deuterium and tritium obtained by asteroids, the mining countries should sell some of them to the non-mining countries at an appropriate lower price, so as to promote greater investment in nuclear power generation in the non-mining countries. For countries without nuclear power generation capacity, the mining countries can convert the nuclear energy released by the mining nuclear power raw materials into the fossil energy needed by ordinary fossil fuels and sell them to the non-mining countries without nuclear power generation at an appropriate lower price.

4.For asteroid mineral resources and fossil energy extracted by mining countries, the United Nations encourages mining countries to make more use of the mineral resources and fossil energy extracted from asteroids to replace the earth for production, so that the consumption of minerals on the earth by mining countries is reduced more than that of non-mining countries.

the picture9

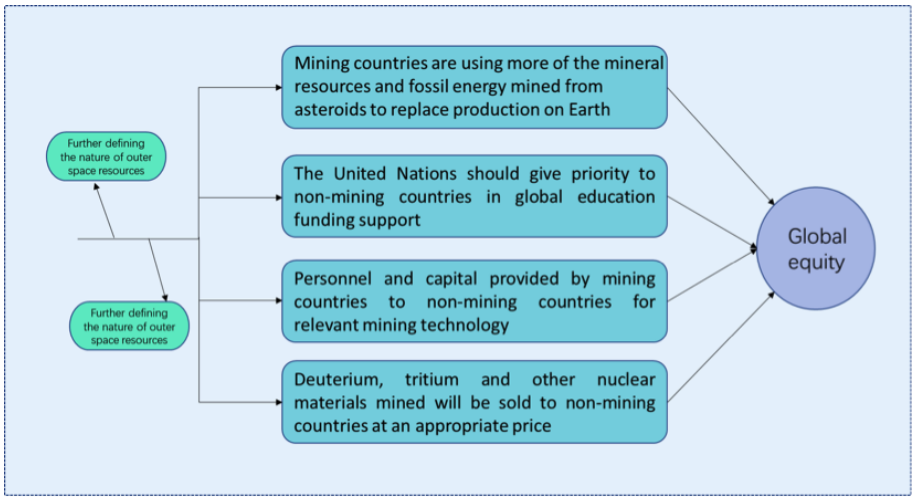

Figure 9: The concept plan of our policy

8 Sensitivity analysis

In this part, we adjust the value of negative externality coefficient α.

We adjust the value of the negative externality coefficient from 0 to 1 in steps of 0.1. As we know from the graphical trends in figure 11 and figure 12, the change in the adjustment coefficient does not affect the change in the number of categories of the intermediate type of the K-means clustering pair. And the mean value of equity ratio

$\bar{E}$ shows a strong negative correlation with the alpha value (slope is -0.3134), and also with the standard deviation of equity ratio E (slope is -0.0026). Thus, the alpha value can most directly affect the overall level of equity ratio, while having some effect on its distribution, but not enough to change the results of clustering.

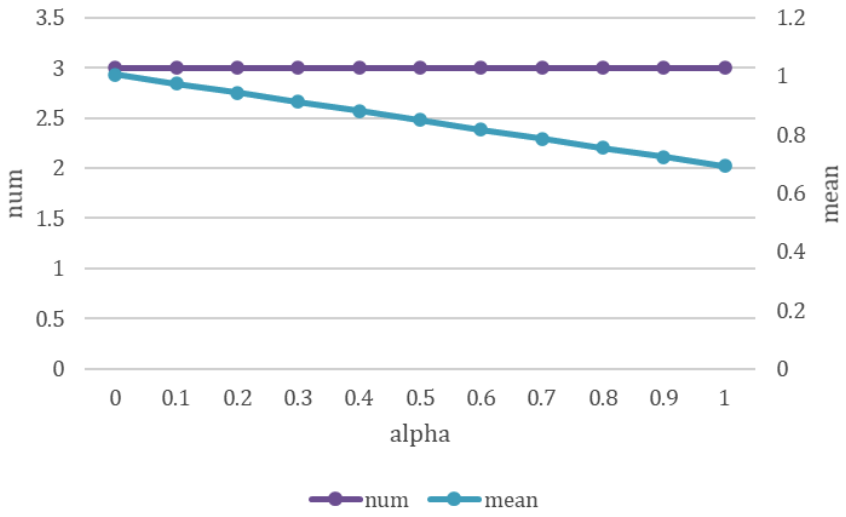

Figure 10: Sensitivity analysis of alpha for num and mean

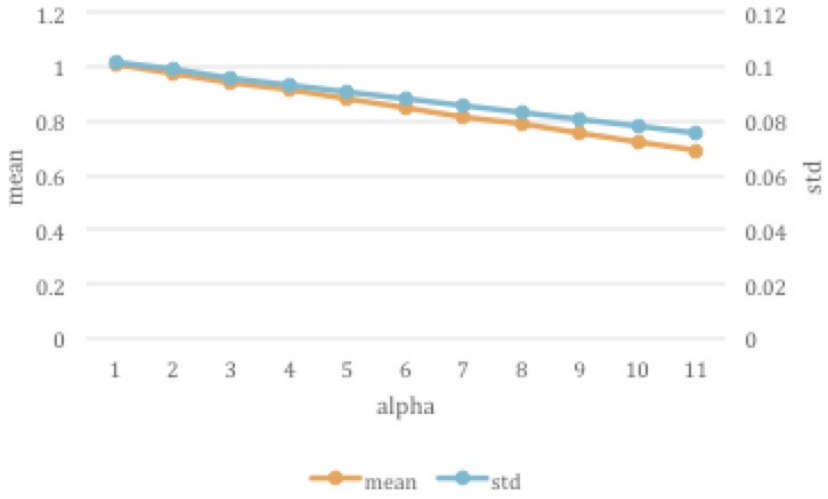

Figure 11: Sensitivity analysis of alpha for std and mean

9 Strengths and Weaknesses

- **Strengths**

  1. Targeted According to the definition of global equity with the country as the smallest unit, we innovatively put forward the ”equity rate” to measure the level of global equity and the distribution of countries.

2. Clustering Results are more objective and convenient. K-means algorithm is used to cluster countries, instead of dividing them by belief. On one hand, the collected data are fully utilized, on the other hand, when the global equity rate is improved, the division standard does not need to be changed manually.

3. Inclusive In the IBH model, the industrial, educational, environmental, and other indicators that may be affected by asteroid mining are integrated, so as to better and pertinently explain the impact of asteroid mining on global equity in the future vision.

- **Weaknesses**

1. The complexity of dynamic programming algorithms is high. The Traversal Method is used to solve the optimal change rate of the input index, which can optimize the algorithm and find the global optimal solution faster.

2. Subjective Some of the parameters used in the model were obtained subjectively. Although we have taken into account many government reports and developments in other countries, these parameters appear to be subjective to some extent.

10 References

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Appendices

Appendix A Appendix

Figure 12: The fitting curve f_2

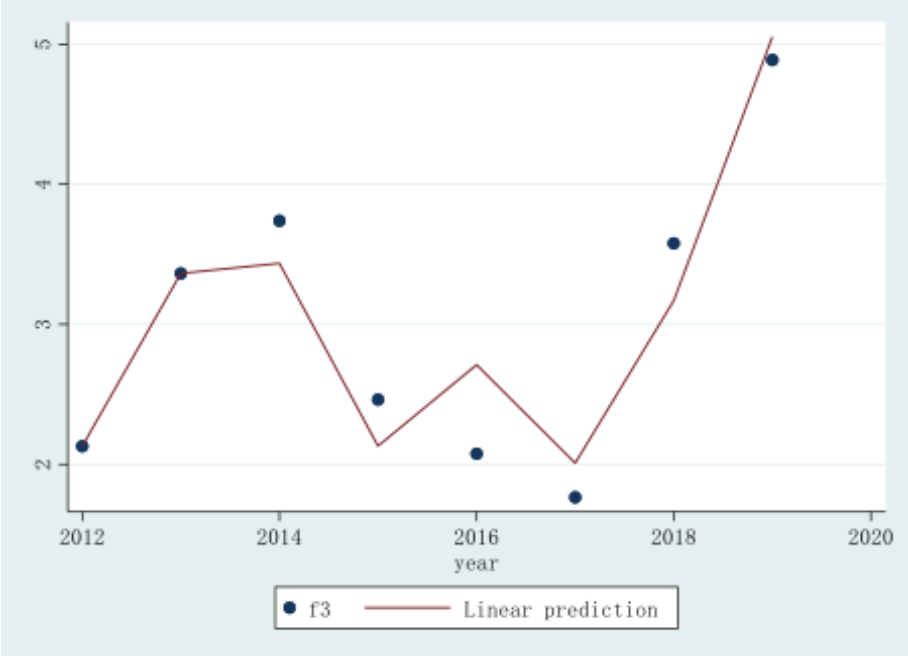

Figure 13: The fitting curve f_3