Research on global equity evaluation model based on resource allocation---Illustrated by the case of asteroid mining

Yuan Feng [1, *], Ge Song [1,] Shujun Ju [2]

[1] Sichuan University Software Engineering College Sichuan, Chengdu, 610225, China

[2] Sichuan University Pittsburgh Institute Sichuan, Chengdu, 610225, China

* Corresponding Author Email: fengyuan0304@163.com

Abstract. When asteroid mining becomes a reality, distributing these resources fairly and reasonably is a new challenge for mankind. In order to establish a scientific global fairness evaluation model based on the three faces of international inequality, we have a total of 13 data from different perspectives from the six aspects of the economy, environment, natural resources, technology, education, and health. Set out to assess global equity. After the principal component analysis of these 13 indicators, we finally selected one indicator for each aspect's main indicator. Subsequently, we considered the calculation methods of various indicator weights and finally chose to use the combination of EWM and TOPSIS to measure more objectively and accurately. After EWM, each data is given a weight, and TOPSIS is used to calculate the annual score of each country. The standard deviation of the annual results is used to describe the degree of inequality between countries through the degree of dispersion of the values between countries. The higher the degree of dispersion, the higher the inequality. We use an autoregressive artificial neural network to predict the future index (standard deviation) using the first five years of each year's World Equality Index as a parameter.

Keywords: Entropy weight method; TOPSIS; Neural Networks; standard deviation.

1. Introduction

With the development of human society, asteroid mining has become a relatively safe and worthy investment option in the future. With the enormous benefits of asteroid mining, it is hard to say with certainty that: at that time, those countries were still willing to recognize the Outer Space Treaty signed in 1967, especially the principle of "shared by mankind" emphasized in it. The asteroid mining industry will increase international inequality when facing the gap between national capabilities and huge interests. Therefore, we urgently need a set of adequate policies to increase the fairness of asteroid mining in the future. Following the example. Some components, such as multi-leveled equations, graphics, and tables, are not prescribed, select proper indicators and build a model or a suite of models to measure global equity.

2. Model for Global Equity

There are 197 countries all around the world. Due to the difference in resources, environment, and historical issues, the countries develop in quite different situations. A man in Europe might be having afternoon tea while a kid in the Middle East suffers from severe conflict. So it is crucial to set up an index for global equity.

According to Human Development Reports from United Nations Development Programme, human being equity is determined mainly by three aspects [1]: long and healthy life, knowledge, a decent standard of living. The key point of this measurement is that it does not only consider the economy, although the UN uses GDP to represent the decent standard of living. This system also views education and life expectancy as critical parts. It is a very comprehensive elevation. However, there are some drawbacks to this system. For example, some countries have considerable resources, and potential economic growth is not considered. Also, some countries may have a tremendous

environmental advantage and focus on sustainable development. These strengths are not revealed in the system.

Therefore, our team chose 11 indices to describe the global inequity initially, which are GES, NLO, GDP, GNI, PA, SII, NW, GHG, DUW, CMR, LE, and PSM, classified in six categories: Economy, Technology, Natural Resources, Environment, Health, and Education. Because the number of the indices varies in different categories, we decide to remove unimportant indices in each category using Principal Component Analysis (PCA).

2.1. Data Description

1) Economy

We use GNI per capita to reflect one county's economic level. GNI is Gross National Income, which is the index representing one country's production level and capacity. It is related to the well-being of citizens. The definition of GNI in our work is:

$$GNI = \frac{(vlaue\ of\ all\ products - value\ of\ intermediate\ product)}{POP} \tag{1}$$

POP is the population of the country.

2) Technology

The share of Individuals using the Internet becomes a vital index in the PCA process, for its characteristic root is 0.48, higher than the other two indices of technology. It is reasonable because Internet access depends on satellite, infrastructure, and information system technology. So it is comprehensive. We get the data from Our World in Data.

$$SII = \frac{individuals\ using\ the\ Internet}{POP}\% \tag{2}$$

3) Natural Resources

Natural resources contain many aspects, and sometimes they cannot be expressed only using the number of one resource. So we use Natural Capital Wealth (NW) per capita (from Our World in Data, retrieved from World Bank database) to describe the level of natural resources.

$$\begin{cases} Land(crop, pasture) \\ .Protected\ areas \\ Fossil\ energy\ resources \\ Metals\ and\ minerals \\ Forest \end{cases} \tag{3}$$

We calculate the sum of all these kinds of natural wealth to represent the total wealth of nature. Then it is divided by the population of one country to represent Natural Capital Wealth (NW) per capita.

4) Environment

The environment is also a crucial reflection of equity. Often, developing countries have lower levels of the environment due to the blossom of low-level industry and vice-versa.

We first collect Green House Gas Emission (GHG) (per capita.) and Percentage of Deaths caused by Unsafe Water (DUW). Because the characteristic root of GHG is much bigger, we choose GHG as the indicator. (Data from Our World in Data)

$$GHG = \frac{total\ emission}{POP} \tag{4}$$

5) Health

We initially chose three indicators, and after PCA, we found that Life Expectancy (LE) has the most extensive characteristic root 0.47. Therefore, we use Life Expectancy to indicate health level.

6) Education

Education is also essential for determining equity. We first choose National average Learning Outcomes (NLO) and Gross Enrollment Rate of Secondary Education (GES). Because GES has the

larger root and the NLO is not precise (Every country has a different education system and it is related to culture. On the contrary, nearly every country has secondary education and all students can gain knowledge or skills from It.), we choose GES as the index. (Data from Our World in Data)

$$GES = \frac{enrollments\ to\ secondary\ education}{POP}\% \tag{5}$$

2.2. Evaluation system using EWM and TOPSIS

After having the six indices for Economy, Technology, Natural Resources, Environment, Health, Education, our team used the Entropy Weight Method to give every index a weight.

In this model, if the indicator has a more considerable variance between countries, this index has more differentiation and can reflect the inequity between the countries. Thus the index has more weight in the system of Global Equity. Firstly, each indicator should be normalized, assuming that there are n samples and each sample has m indicators:

$$X_1, X_2, ..., X_m \tag{6}$$

Where

$$X_i = \{x_1, x_2, ..., x_n\} \tag{7}$$

Assume that the standardized value of each indicator data is

$$Y_1, Y_2, ..., Y_m \tag{8}$$

If it is a positive indicator

$$Y_{ij} = \frac{X_{ij} - MIN(X_i)}{MAX(x_i) - MIN(x_i)} \tag{9}$$

If it is a negative indicator, then

$$Y_{ij} = \frac{MAX(X_i) - X_{ij}}{MAX(x_i) - MIN(x_i)} \tag{10}$$

Then, the ratio of each indicator under each plan is calculated. The proportion of the JTH indicator in the ith sample is used to calculate the variation of this indicator:

$$p_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{n} Y_{ij}} \quad i = 1, ..., n \quad j = 1, ..., m \tag{11}$$

According to the definition of information entropy in information theory, the information entropy of a group of data is:

$$E_j = -ln(n)^{-1} \sum_{i=1}^{n} p_{ij} ln p_{ij} \tag{12}$$

According to the calculation formula of information entropy, the information entropy of each index is calculated as:

$$E_1, E_2 ..., E_m. \tag{13}$$

Then the weight is calculated by calculating information redundancy:

$$D_j = 1 - E_j. \tag{14}$$

Finally, calculate the index weight:

$$w_j = \frac{D_j}{\sum_{j=1}^{m} D_j} \tag{15}$$

After calculation, the weight of technology is 0.2220, the weight of health is 0.0766, the weight of education is 0.0855, the weight of economy is 0.2461, the weight of Resources is 0.3003, and the weight of environment is 0.0695. We will use this weight to conduct TOPSIS for each country to calculate the Score of Global Equity (SGE).

In our model, there are six basic aspects (six indicators) to evaluate each country's score. Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) can be used to get each country's relative strength and weakness among all countries. We describe the results of TOPSIS using the Score of Global Equity (SGE, which is f (i) in the following part). Moreover, we define the standard deviation f (i) (SGE) to represent the global equity level. Here we define WEI as a global equity index. The smaller WEI is, the more equal countries are.

First, the normalized national index matrix Y in the entropy weight method above is multiplied by the weight matrix W to obtain the weighted index matrix C:

$$C_{ij} = w_j * Y_{ij} \quad i = 1...n \quad j = 1...m \tag{16}$$

Determine the optimal solution C* and the worst solution C° :

$$C_j^* = \begin{cases} MAX_{(i)}C_{ij} & j\ is\ Positive\ indicator \\ MIN_{(i)}C_{ij} & j\ is\ Negative\ indicator \end{cases} C_j^{\circ} = \begin{cases} MAX_{(i)}C_{ij} & j\ is\ Negative\ indicator \\ MIN_{(i)}C_{ij} & j\ is\ Positive\ indicator \end{cases} \tag{17}$$

Calculate the distance of each index to the optimal solution and the worst solution.

C_I

$$s_i^* = \sqrt{\sum_{j=1}^{m}(C_{ij} - C_j^*)^2} \quad i = 1...n \tag{18}$$

Calculate the total ranking index value of each national indicator (i.e., comprehensive evaluation index), namely:

$$SGE = f_i = \frac{s_i^{\circ}}{s_i^{\circ} + s_i^*} \quad i = 1...n \tag{19}$$

The standard deviation of the total score of each country was calculated to measure the degree of dispersion, and the world inequality index WEI was obtained:

$$WEI = \sqrt{\frac{\sum_1^n (f_i - mean(f_i))^2}{n-1}} \tag{20}$$

2.3. Prediction system using ANN neural network

ANN is a complex network structure composed of many processing units (neurons) connecting. It can predict future change precisely [2]. We use it to predict the **SGE** and **WEI** change, as shown in Figure 1.

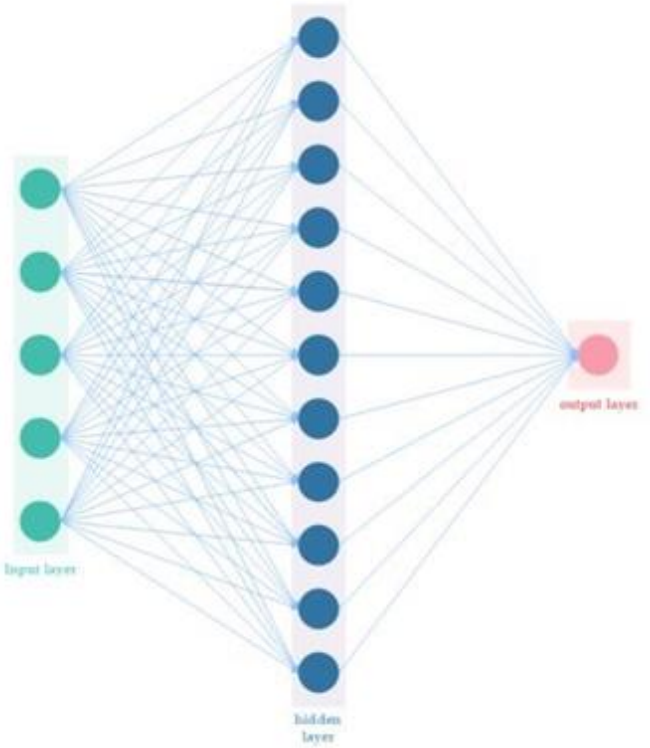


Figure 1. Structure diagram of artificial neural network.

3. Evaluation of the policy implementation using our models

We decided to establish a neutral and authoritative international organization, the International Space Resources Administration (ISRA). ISRA has the right to collect mining taxes on any country and company that conducts asteroid mining. Because it does not involve purchasing mining property rights, the planetary mining industry tax rate will be higher than the earth mining industry tax rate under the same conditions. We only go for a cumulative tax system based on production in terms of planetary mining tax rates. The definition of a progressive tax is that it takes a large percentage of income from the high-income earners than it does from the low-income earners. Therefore, a progressive tax system is effectually a means to redistribute income from the high-income earners to the low-income earners. Subsequently, the government revenues collected from a progressive tax system can be used to fund social programs designated for the lower-income groups for a more equitable society. [3]

Our Global Equity evaluation model comprehensively obtains a global equity index from six aspects: economy, environment, natural resources, technology, education, and health. Since asteroid mining has little effect on the health of countries, we will consider the effect of policy implementation from the remaining five points.

Economy: After implementing the cumulative tax system and production restriction policy, we can essentially limit the expansion of the oligopolies in the asteroid mining industry compared to the situation without policies. The GNI of those developed countries will likely be reduced from an extremely high level to a reasonable range. On the other hand, developing countries that the Outer Space Foundation has helped will gradually master the related technologies and support planetary mining financially. Thus, they can have their place in the planetary mining industry. Besides, after receiving humanitarian aid, the developing countries will also be better off than before. Therefore, the GNI of these two types of countries will increase to a certain extent compared to no-policy-situation. According to our estimates, the GNI rise in developing countries is about 5% per year [4].

Environment: According to the article Exploring Potential Environmental Benefits of Asteroid Mining, collecting 1kg of platinum in an asteroid will release about 60kg of CO_2. In contrast, the

global warming effect of collecting the same mass of platinum on Earth is large than that in space. Magnitude. [5] With no policy constraints, only countries that can mine planets will have lower greenhouse gas emissions, and the gap between countries will increase. As more and more countries participate in planetary mining, their greenhouse gas emissions will drop significantly compared to before, and the countries will slowly converge.

Natural resources: The mining of ore in space between countries is not limited by its natural geographical factors but by its technological level and investment capacity. Before the policy was implemented, many planetary mineral resources were in the hands of a few countries or enterprises. With the limited production and the technical and financial support of the Outer Space Foundation, more and more countries and people will enjoy planetary mineral resources. With the assumed constant price of ore, the output increment owned by each country becomes more evenly, and the share of natural capital wealth per person becomes more similar across countries. At the same time, this is also a concrete manifestation of the principle of "human sharing" in the United Nations Outer Space Treaty.

Technology and Education: The technical support and humanitarian fund in the Outer Space Foundation have contributed to the development of technology and education in developing and relatively backward countries. The Figure 2 below shows the difference in the Global Equity Index (WEI) before and after implementing the policy, as predicted by our ANN model after humans begin to mine asteroids.

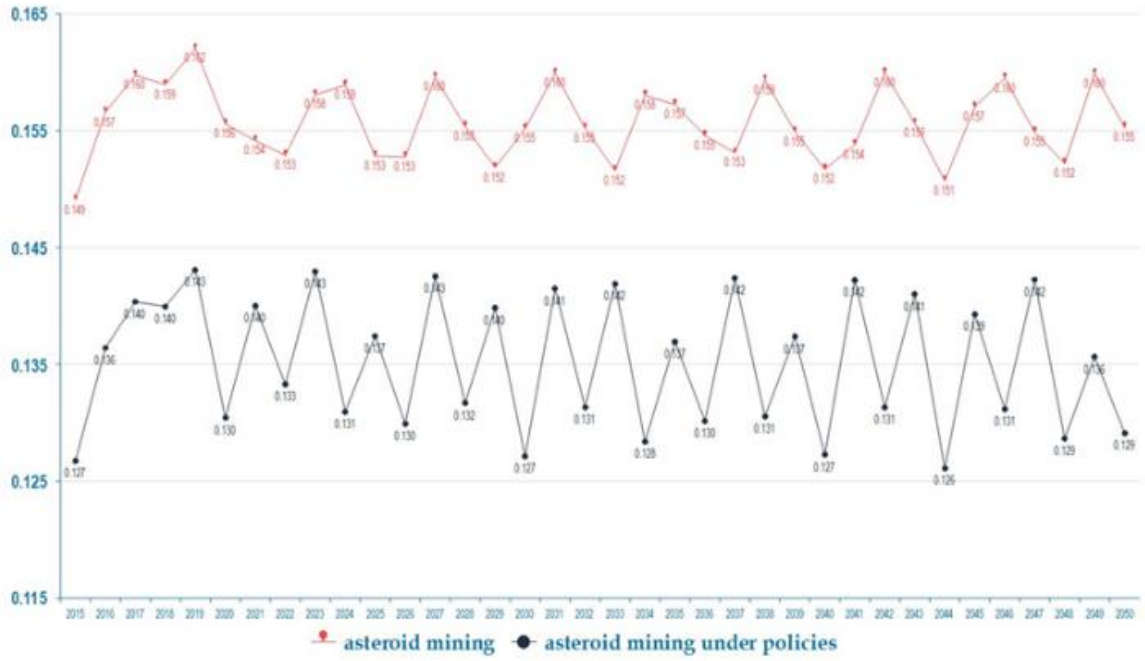


Figure 2. The Global Equity Index (WEI) before and after implementing the policy.

Obviously, after implementing our policies, the global equity index is closer to zero, which means that the world is becoming more equitable.

4. Conclusion

The model in this paper is practical and straightforward. In the case of known national indicators, the world equality index can be calculated easily. The model in this paper is innovative. We describe the quality of life of a country with six essential aspects. The selected parameters are all per capita indicators, which can objectively describe the quality of life enjoyed by citizens worldwide. The parameters selected by the model in this paper are highly representative, which describe aspects comprehensively and can be applied to every country with good universality. Instead of the absolute

values, we adopt the TOPSIS method to comprehensively evaluate each country's relative merits and demerits, which can better reflect the differences between countries. We use a neural network instead of ordinary linear regression, which makes the prediction results of the future world equality index more accurate and reliable. Besides, to make it more realistic, we calculate the future demand for asteroid mining based on the Earth's depletion rate and how much each country can produce.

The six aspects of the economy, environment, health, technology, natural resources, and education can be effectively called indicators for judging international equality according to different weights. When asteroid mining is carried out without policy restrictions, international disparities in the economy, environment and natural resources will widen, increasing international inequality. With the implementation of the policy framework of the International Space Resources Administration, under the two major policies of production restrictions and humanitarian assistance, the international gaps in the economy, environment, and natural resources will be reduced, international inequality will be reduced.

References

[1] Mathematica Policy Research Inc., P.O. Box 2393, Princeton, NJ 08543-2393, United States b Pennsylvania State University, United States.

[2] Application research of optimal combination prediction method based on neural network [J]. Systems engineering-theory & practice, 2 001, 21(9):90-93. DOI:10.3321/j.issn:1000-6788.2001.09.016.

[3] Papanikolaou, Nikolaos.2021. Tax Progressivity of Personal Wages and Income Inequality. Journal of Risk and Financial Management 14: 60. https://doi.org/10.3390/ jrfm14020060.

[4] Agreement Relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982, Annex II, Section 7, para.1. United Nations Convention on the Law of the Sea.

[5] Andreas Makoto Hein, Michael Saidani, Hortense Tollu. Exploring Potential Environmental Benefits of Asteroid Mining. 69th International Astronautical Congress 2018, Oct 2018, Bremen, Germany. Hal-01910090.