# Global equity analysis of asteroid mining based on RCSS

Xuanxuan Li[1, *] Yiwei Zhu[2] Kangyan Wang[3]

[1]School of Business and Management, Jilin University, Changchun, Jilin, 130000

[2]School of Mechanical and Electrical Engineering, Shenyang Aerospace University, Shenyang, Lia oning, 110136

[3]College of Electrical Engineering and Control Science, Nanjing Tech University, Nanjing, Jiangsu, 210000

*Corresponding author. Email: lxx220419@163.com

**Abstract.** As mining and exploitation of asteroid mining becomes possible, its relationship with global equity becomes a hot topic of discussion. It is significant to establish a scientific and sustainable equitable distribution. In this paper, EWM is used to calculate the weight of secondary indicators, and RCSS model is used to reflect the overall development level of the region. By calculating the variation degree of development level between CV reaction regions. Combined with the results of RCSS model, the secondary index scores are analyzed to illustrate the different ways in which asteroid mining affects the global equity level and impact degree.

**Keywords:** Entropy Weighting Method; AHP; asteroid mining; global equity.

## 1. Introduction

With the development of science and technology and the deepening of space exploration, in the face of the endless resources and wealth contained in space, human beings can no longer be satisfied with understanding and understanding space, but turn to how to use and develop the rich fuel oil, precious metals and other mineral resources that may be contained on asteroids [1-2].

When asteroid mining is assumed to be feasible and profitable in the future, problems related to global equity arise [3].

Including how it affects the economy (such as GDP growth rate, GNI, etc.), or how it affects social development, climate environment and national system [4]? How do these indicators affect global equity? How can asteroid mining develop in the direction of promoting global equity, so as to truly benefit all mankind? These questions have yet to be answered [5]. Therefore, the improvement and updating of the outer space treaty is essential for all mankind and the process of global equity [6].

Considering the background, in this paper we select proper indicators and build a model or a suite of models to evaluate global equity [7]. Apply the model to assess the similarity of regional development level in various regions to reflect the degree of global equity [8-9].

## 2. Establishment And Solution Of Model

### 2.1. RCSS Indicator System

To build the Regional Comprehensive Strength Score (RCSS) indicator system, we need to select representative indicators. In our previous study, we summarized different regional comprehensive strength indicator systems around the world. Through comparison, the five-in-one indicator framework is universal and reasonable. According to figure 1.

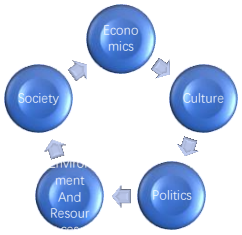



**Figure 1.** The five-in-one indicator framework

Then, we combined the influencing factors and the principles of index selection in the relevant reference literature, and finally selected 14 secondary indicators to establish a complete index system. Here, we introduce our indicator system. According to table 1.

**Table 1.** Indicator system

| Level 1 | Level 2 | | Unit |
|---|---|---|---|
| Economics | GDP | GDP growth (annual %) | % |
| | GNI | GNI, Atlas method (current US$) | number |
| Society | CHE | Current health expenditure (% of GDP) | % |
| | UP | Urban population (% of total population) | % |
| | AE | Access to electricity (% of population) | % |
| | IUI | Individuals using the Internet (% of population) | % |
| Culture | SE | School enrollment, tertiary (% gross) | % |
| | STA | Scientific and technical journal articles | number |
| Environment And Resources | CO2 | CO2 emissions (metric tons per capita ) | number |
| | WP | Water productivity, total (constant 2015 US $ GDP per cubic meter of total freshwater withdrawal) | % |
| | EP | Electricity production from renewable sources, excluding hydroelectric (% of total) | % |
| | FA | Forest area (% of land area) | % |
| Institution | UT | Unemployment, total (% of total labor force) (modeled ILO estimate) | % |
| | SLR | Strength of legal rights index (0=weak to 100=strong) | number |

The indicators requiring special clarification are GNI and SLR.GNI is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad.

Strength of legal rights index measures the degree to which collateral and bankruptcy laws protect the rights of borrowers and lenders and thus facilitate lending. The index ranges from 0 to 12, with higher scores indicating that these laws are better designed to expand access to credit.

### 2.1.2 Data Pre-processing

Data Filling: Because of the limited access to national data, the data have some missing values. To deal with this problem, we adopt the following approaches.

- If a certain indicator of a region has rather few missing data of the years and the indicator has a relatively small variance, we adopt the mean completer method and use the average value of other years to fill the missing one.
- If a certain indicator of a region has rather few missing data of the years and the indicator has a relatively strong correlation with the year indicator, we use the regression interpolation method.
- If a certain indicator of a region lacks data for all years, we fill in the data of this indicator with the mean of all countries considering the specific meaning of the indicator.

Handling Outliers: Through descriptive statistics and box plots, we analyzed each indicator in all countries and found some highly abnormal outliers that deviated from the mean by more than twice the standard deviation.

- For data with a significant level of $\alpha<0.01$, we discarded it and processed it according to the above-mentioned missing value processing method.
- We also found data that clearly deviated from the actual meaning, for example, the enrollment rate exceeded 100%. We also discarded these outliers.

### 2.1.3 Data Normalization

We divided the 14 secondary indicators into 2 categories, and standardized each of the 2 categories into.

1.Positive indicators

Since the larger absolute value of positive indicators is better for sustainability, their standardization formula is

$$r_{ij} = \frac{x_{ij}}{max_j\,(x_{ij})} \tag{1}$$

Where $max_j$ ($x_{ij}$) is the best value of the positive indicator, *i.e.*, the maximum value of indicator *i* among all *m* sample countries.

2. Negative indicators

Since smaller absolute values of negative indicators are better for sustainability, their normalized formula is defined as

$$r_{ij} = \frac{min_j\,(x_{ij})}{x_{ij}} \tag{2}$$

where $min_j$ ($x_{ij}$) is the optimal value of the negative indicator, *i.e.*, the minimum value of indicator *i* among all m sample countries.

Based on the above equation, the formula for the ratio of each indicator value can be obtained as

$$f_{ij} = \frac{r_{ij}}{\sum_{j=1}^{m} r_{ij}} \tag{3}$$

### 2.1.4 Calculate RCSS- EWM And AHP

We introduce the regional comprehensive strength score (RCSS) as an overall description of the development level of a region.

The entropy weight method (EWM) is commonly used as a weighting method that measures value dispersion in decision-making. It assumes that the greater the degree of dispersion, the greater the degree of differentiation, and more information can be derived. Thus, higher weight should be given to the index, and vice versa[10]. We use the entropy weight method to estimate the weight values of the second-level indicators.

Suppose we have *n* indicators and *m* regions in total.

We first standardize the measured values. The standardized value of the $i^{th}$ indicator of the sample region *j* is denoted as $p_{ij}$.

$$p_{ij} = \frac{\tilde{x}_{ij}}{\sum_{j=1}^{m} \tilde{x}_{ij}} \tag{4}$$

$$Where\ i = 1,2\ldots, n;\ j = 1,2, \ldots, m$$

In EWM, the entropy value $E_i$ of the $i^{th}$ indicator is calculated.

$$E_i = \frac{\sum_{j=1}^{m} p_{ij} ln p_{ij}}{\ln m} \tag{5}$$

The larger the $E_i$ is, the greater the differentiation degree of index *i* is, and higher weight should be given to the index. Therefore, the weight $w_i$ of index *i* is calculated as follows.

$$w_i = \frac{1-E_i}{\sum_{i=1}^{n}(1-E_i)} \quad (6)$$

Then, we get the weight value vector of each three dimensions. The comprehensive performance of sample *country*$_j$ by considering the total *n* indicators can be obtained as

$$S_j = \sum_{i=1}^{n} w_i \, p_{ij} \quad (7)$$

Since our indicator system is divided into five dimensions, that is, economic, political, cultural, social and ecological civilization. Therefore, we apply EWM to these five dimensions and calculate five scores to get the score of regional comprehensive strength. According to table 2.

**Table 2.** The indicators' weights

| | Indicator | Weight |
|---|---|---|
| Economics | GDP growth (annual %) | 0.090931104 |
| | GNI, Atlas method (current US$) | 0.120950554 |
| Society | Current health expenditure (% of GDP) | 0.089647581 |
| | Urban population (% of total population) | 0.065416906 |
| | Access to electricity (% of population) | 0.036666968 |
| | Individuals using the Internet (% of population) | 0.093105308 |
| Culture | School enrollment, tertiary (% gross) | 0.073715275 |
| | Scientific and technical journal articles | 0.121880287 |
| Environment And Resources | CO2 emissions (metric tons per capita ) | 0.036841087 |
| | Water productivity, total (constant 2015 US $ GDP per cubic meter of total freshwater withdrawal) | 0.063515978 |
| | Electricity production from renewable sources, excluding hydroelectric (% of total) | 0.065504666 |
| | Forest area (% of land area) | 0.044229814 |
| Institution | Unemployment, total (% of total labor force) (modeled ILO estimate) | 0.047349596 |
| | Strength of legal rights index (0=weak to 100=strong) | 0.050244877 |

Next, to find the weights of the four dimensions, we adopt AHP method. The weight value vector is

W=(0.4441, 0.2414, 0.0561, 0.1649, 0.0932)

### 2.2. Definition and Calculation of Global Equity

Definition: Through the review and summary of relevant literature, we believe that global equity is that countries and regions all over the world use opportunities and resources to have similar outcomes, the development level is getting closer and closer, and finally achieve the common prosperity of all mankind.

Calculation: We derived the overall strength score values for the selected regions. According to table 3.

**Table 3.** The score of regions

| Region | |
|---|---|
| Middle East & North Africa | 0.016807606 |
| North America | 0.040985534 |
| South Asia | 0.018619511 |
| Sub-Saharan Africa | 0.015404141 |
| East Asia & Pacific | 0.035151618 |
| Latin America & Caribbean | 0.022932836 |

| | |
|---|---|
| Europe & Central Asia | 0.039918497 |

Finally, we measured the degree of similarity between the composite strength scores of each region using the coefficient of variation, with the formula

CV = (Standard deviation / Mean) × 100%

The result obtained is 41.34%.

## 3. Impact of Asteroid Mining on Global Equity




**Figure 2** The kind of indicators

We indict the GDP growth in developed regions is more pronounced, so it will lead to a significant increase in CV; the GNI in developed regions will grow more than in less developed regions, so CV will increase; the economic growth lead to increasing the urban population, and developed regions will be more sensitive to this indicator, so CV increases; the school enrollment is more evident in educationally developed regions, it leads to a decrease in the medium amplitude of CV; the STA in developed regions will increase significantly. Instead, for the less developed regions, the STA will only have a small increase, and CV will increase in the medium range. However, there will be a small decrease in CHE in the global view, which will have little effect on CV; the access to electricity, the individuals using the internet and the unemployment will lead to CV decrease in different degree. The amount of $CO_2$ emissions also will be reduced. And the CHE, the WP, the EP, the FA and the SLR will have little effect on CV.

On the whole, the value of CV will become larger, the difference of development level between regions becomes larger, and the global unfair increases.

## 4. Conclusion

For the subject engaged in mining, asteroid mining is a beautiful idea, but there are many technical hurdles between reality. As for China, although asteroid resource development will definitely be one of the future directions of space development, the road to asteroid mining in China is still very long and distant for the lack of complete funding and the lack of abundance of cutting-edge technology. In summary, the backbone of asteroid mining is still the well-funded and technologically advanced developed countries.

For the investment body, if space mining is highly profitable, private companies will have the largest share of funding, and governments and international funding organizations will have a smaller share of funding, or even governments will only have a regulatory role and not funding. If space mining focuses on the distribution of profits for all mankind, international funding organizations will

have the largest share of funding, followed by national governments, and finally private companies, even if private companies will not invest.

For the subject of obtaining benefits, if policies are not updated and improved in a timely manner, as things stand now, the countries with the greatest opportunity to profit from the minerals themselves or from their sales will be the more powerful countries with the combined power to conduct asteroid mining, thus exacerbating the polarization of the world's rich and poor.

## References

[1] Morgan Sterling Saletta, Kevin Orrman-Rossiter. Can space mining benefit all of humanity? The resource fund and citizen's dividend model of Alaska, the ‘last frontier’, Space Policy, Volume 43, 2018, Pages 1-6, ISSN 0265-9646.

[2] Skauge, T. (2020). Space mining & exploration: Facing a pivotal moment. Journal of Corporation Law, 45(3), 815-832.

[3] Christensen, I., Lange, I., Sowers, G., Abbud-Madrid, A., & Bazilian, M. D. (2019). New policies needed to advance space mining. Issues in Science and Technology, 35(2), 26-30.

[4] Asteroid missions face delays and resets [J]. Space Industry Management,2017(02):48.

[5] Sun Hai. Aerospace academician: China can go to asteroid mining within 10 years if it wants to do it[J]. Computers and Networks, 2017, 43(20):17.

[6] Global space mining market 2025: Global space mining market is expected to be worth USD 14. 71 billion between FY2018-25. space mining is set to usher in a new era of space exploration and commercialization. (2020, Jan 17).

[7] Zhang Shaojie, Yang Xueli. Construction of China's Food Security Evaluation System Based on Development Theory and Reform, 2010(02):82-84.

[8] Leon. Mining for meaning: an examination of the legality of property rights in space resources. Virginia Law Review, 104(3), 497–546.

[9] Xu Hui. Deep Space Industries mining company to launch asteroid prospecting program in 2020[J].Resource Environment and Engineering, 2016, 30(06):1033.

[10] Cai Yuwen and Liu Can. Comparative analysis of r&d input and output of major countries (regions) in the world. Bulletin of National Natural Science Foundation of China, 4(2): 442–448, 2018.