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Study of the Impact of Asteroid Mining on Global Equity

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Abstract

In this paper, we build a global equity measurement model to measure global equity by selecting 5 output indicators and 3 input indicators in 15 countries, we use the entropy weight method to measure the input and output of 15 countries sorted. Furthermore, we forecast future inputs and outputs for 15 countries using auto regressive integrated moving average (ARIMA) model and Fourier series fitting. Finally, we analyze the impact of changes in compensation returns on global equity.

Keywords

Global Equity; Entropy Weight Method; Asteroid Mining; Auto Regressive Integrated Moving Average (ARIMA).

1. Introduction

Most countries in the world have signed the outer space treaty issued by the united nations in 1967, agreeing that “the exploration and use of outer space, including the moon and other celestial bodies, shall be for the benefit and benefit of all nations, regardless of their degree of economic or scientific development, and shall be for the benefit of all mankind” [1].

The development of outer space resources has always attracted the attention of domestic and foreign academic circles. The “agreement governing the activities of states on the moon and other celestial bodies” emphasizing adopted by the united nations in December 1979 emphasized “determination to promote the further development of cooperation among countries in the exploration and utilization of the moon and other celestial bodies on an equal basis”, aiming to maintain global equity in the exploration of lunar resources [2]. A techno-economic analysis of asteroid mining was conducted to provide basic experience for future technology development [3]. The article mainly discusses the delicate relationship between space mining and the outer space treaty [4]. The authors of [5] conducted a study on reflections on policy and legal issues related to the development and utilization of outer space resources.

In this paper, we develop a model to measure global equity, examining the impact of changes in asteroid mining on global equity. By analyzing the global equity index (GEI), we found that three of the eight indicators of the global equity measurement Model are strongly correlated with mining returns. Using the ARIMA model to forecast inputs and outputs, it is found that mining has a positive effect on global equities. Finally, we analyze the impact on global equity of changes in compensation returns, analyzing the sensitivity of the models under consideration.

2. The Global Equity Index Model

2.1. Model Establishment

Considering the data volume of the sample, this paper uses the entropy weight method to determine the objective weight of each index according to the size of the variability [6].

Taking the determination of the weight of intellectual property income in the allocation of outer space resources as an example, suppose x represents the possible situation in the intellectual

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property income, and $p(x)$ represents the probability of this situation occurring. On this basis, the amount of information $I(x) = -\ln\big(p(x)\big)$can be defined, because $0 < p(x) < 1$, so $I(x) \geq 0$, so $I(x) \geq 0$. Denoting the possible situations of intellectual property income as $x_1, x_2, \dots, x_n$, then the information entropy of intellectual property income can be defined as:

$$H(X) = \sum_{i=1}^{n}[p(x_i)I(x_i)] = -\sum_{i=1}^{n}\big[p(x_i)\ln\big(p(x_i)\big)\big] \tag{1}$$

Assuming that there are n objects to be evaluated and the positive matrix composed of m evaluation indicators is as follows:

$$\mathrm{X} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \tag{2}$$

Let the standardized matrix be Z, and the elements in Z are denoted as z_{ij}:

$$z_{ij} = \frac{z_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \tag{3}$$

To judge whether there are negative numbers in the Z matrix, if there is, it is necessary to use another standardization method to standardize the matrix X once to obtain the Z matrix. The standardization formula is:

$$z_{ij} = \frac{x_{ij} - \min\{x_{ij}, x_{2j}, \cdots, x_{nj}\}}{\max\{x_{ij}, x_{2j}, \cdots, x_{nj}\} - \min\{x_{ij}, x_{2j}, \cdots, x_{nj}\}} \tag{4}$$

This ensures that z_{ij} is in the [0,1] interval, and there are no negative numbers.

Supposing there are n objects to be evaluated, m evaluation indicators, and the non-negative matrix obtained after the previous step is:

$$Z = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1m} \\ z_{21} & z_{22} & \cdots & z_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ z_{n1} & z_{n2} & \cdots & z_{nm} \end{bmatrix} \tag{5}$$

Calculating the probability matrix P, where the calculation formula of each element p_{ij} in P is as follows:

$$p = \frac{z_{ij}}{\sum_{i=1}^{n} x_{ij}} \tag{6}$$

It is guaranteed that the sum of each column is 1, that is, the probability sum corresponding to each indicator is 1.

For the j-th index, the calculation formula of its information entropy $\mathrm{e_j}$ is:

$$e_j = -\frac{1}{lnn}\sum_{i=1}^{n} p_{ij}\ln\big(p_{ij}\big), \quad (j = 1,2,\cdots m) \tag{7}$$

where $e_j \geq 0$. If $p_{ij} = 0$ define $p_{ij} = 0$

For the j-th indicator, the information utility value $\mathrm{d_j}$ is calculated as:

ISSN: 2688-9323

$$d_j = 1 - e_j, \quad (j = 1,2,\cdots m) \tag{8}$$

For the j-th indicator, the calculation formula of its weight w_j is:

$$w_j = \frac{d_j}{\sum_{i=1}^{m} d_j}, \quad (j = 1,2,\cdots m) \tag{9}$$

$$R^i = 0.3S_d^i + 0.7\tau_i\left(S_d^i + S_d' S_t^i\right), i = 1, \ldots, 15 \tag{10}$$

Taking the investment in science and technology as an example, the scoring formula is as follows:

$$R(e)_i = \sum_{j=1}^{4} w_j \cdot p_{ij} \quad , \quad (j = 1,2,\cdots 4) \tag{11}$$

The calculation formula of GEI is:

$$\text{GEI} = \frac{n_c}{n} \quad (j = 1,2,\cdots m) \tag{12}$$

where n_c is the number of countries with the same ranking, and n represents the number of all countries.

2.2. Model Analysis

According to the data obtained by inquiring relevant information, we calculated the influencing factors of science and technology investment and resource allocation according to the relevant data of 15 countries, and obtained the weights of their influencing factors as shown in table 1 and table 2.

Table 1. Weight table of influencing factors of science and technology investment

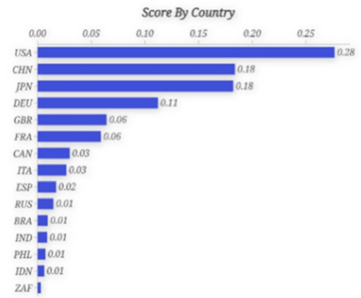
index	GDP	GDP per capita	intellectual property revenue	triadic patent families	high-tech exports
w_j	0.16261	0.08742	0.26259	0.26335	0.22403

Table 2. Resource allocation influencing factor weight table

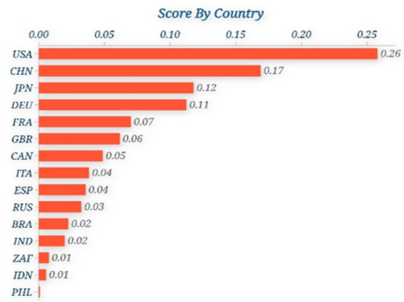
index	research funding	scientific research intensity	R&D researchers per million people
w_j	0.52471	0.27930	0.19599

From table 1 and table 2, it can be found that the national scientific research expenditure has a greater impact on the scientific and technological investment, and the intellectual property income and the number of tripartite patents have a greater impact on the resource allocation. According to the weights of the impact factors obtained above, the scores of scientific and technological inputs and the allocation of space resources of each country are calculated. The sorting results in 2019 are shown in the Fig.1(a) and (b).

From Fig.1, we can know that the number of countries with the same ranking, the $2000 - 2010$ Global Equity Index GEI = 73.33% is finally obtained, which is fair. We selected the data of these 15 countries from 2011 to 2020 to test the model, and obtained an average coincidence index of 74.67%, which is close to the two values. In the 21st century, the development of the world is relatively stable, and the world's equity has not changed much, so our model has practical significance.



(a)



(b)

Figure 1. Score ranking comparison chart by 15 countries

3. Impact of Asteroid Mining Strategy on Global Equity

The initial allocation of mining capital investment and mineral incomes obtained from mining in 15 countries is shown in Fig. 2.

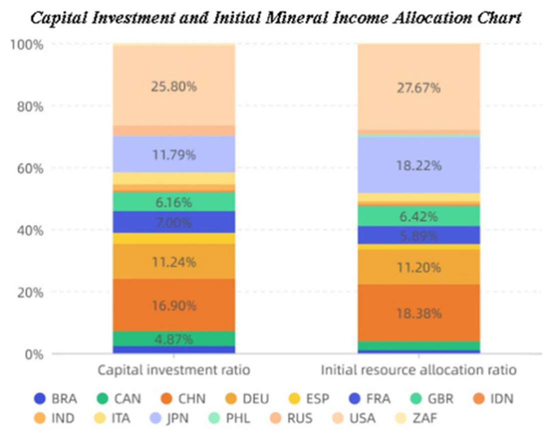


Figure 2. Capital investment and initial mineral income allocation chart

3.1. Technology and Mineral Income Exchange Model

Regarding the exchange of mineral incomes and technology, we are inspired by the technology stocks in the company's share structure. According to the provisions of the “Company Law”, the monetary contribution of all shareholders shall not be less than 30% of the registered capital of the limited liability company [7].

By querying relevant information, we get the data of these 4 indicators of these countries [8]. The entropy weight method is used to determine the weights of these four indicators, and the results are shown in table 3.

ISSN: 2688-9323

Table 3. Indicator weight table

Index	Number of rockets launched	Number of satellites in orbit	Launch success rate	Number of detectors
Weights	0.21458	0.39599	0.08963	0.29981

Based on the above analysis, the calculation model of the final mineral income allocation ratio is introduced, which can be expressed as:

$$R^i = 0.3S_d^i + 0.7\tau_i\left(S_d^i + S_d' S_t^i\right), i = 1, \ldots, 15 \tag{13}$$

where $R^i(\,i = 1, \ldots, 15)$ is the resource allocation ratio of country i, S_d^i is the initial resource allocation ratio of the country, S_t^i is the allocation ratio of the country's exchanged mineral income, S_d' is the total amount of mineral income allocated by all countries without asteroid mining technology. The definition of the characteristic function τ_i is as follows:

$$\tau_i = \begin{cases} 1, & \text{Country i has asteroid mining technology} \\ 0, & \text{National Asteroid} - \text{Free Mining Technology} \end{cases} \tag{14}$$

3.2. The Establishment of the Model of the Impact of Strategy on Global Equity

Therefore, the auto regressive integrated moving average (ARIMA) model can be used to predict their changes directly [9]. Difference autoregressive moving average model, its basic model can be expressed as ARIMA(p, q, d), where p is the order of the autoregressive model, d is the difference order, and q is the number of moving average terms.

$$\left.\begin{matrix} \left.\begin{matrix} \mathrm{AR}(p) \\ \mathrm{MA}(q) \end{matrix}\right\} \mathrm{ARMA}(p, q) \\ \mathrm{I}(d) \end{matrix}\right\} \mathrm{ARIMA}(p, q, d) \tag{15}$$

p-order autoregressive model AR(p):

$$y_t = \delta + \varphi_1 y_{t-1} + \cdots + \varphi_p y_{t-p} + u_t \tag{16}$$

where u_t is the white noise of the time series y_t at point t, and p is the autoregressive order.
q-order autoregressive model MA(q):

$$y_t = u + u_t + \theta_1 u_{t-1} + \cdots + \theta_q u_{t-q} \tag{17}$$

where q is the moving (sliding) average number of terms.
Autoregressive moving average model ARMA(p, q):

$$y_t = \varphi_1 y_{t-1} + \cdots + \varphi_p y_{t-p} + \delta + u_t + \theta_1 u_{t-1} + \cdots + \theta_q u_{t-q} \tag{18}$$

where p is the autoregressive model order and q is the number of moving average terms.
The $ARIMA(p, q, d)$ model can be written as:

$$\omega_t = \varphi_1 \omega_{t-1} + \cdots + \varphi_p \omega_{t-p} + \delta + u_t + \theta_1 u_{t-1} + \cdots + \theta_q u_{t-q} \tag{19}$$

where $\omega_t = \Delta^d y_t$.
The schematic diagram of the ARIMA(p, q, d) model flow is shown in Fig.3.

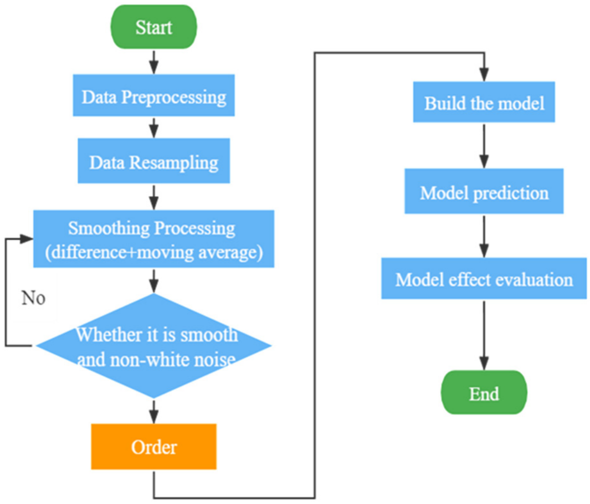


Figure 3. ARIMA Forecast Flowchart

In order to measure the impact of asteroid mineral income on GDP. Based on the assumptions, we first consider the impact of the Earth's mineral output on GDP. Let the GDP of country j in year i be $y_{i,j}$, and the total production value of earth's mineral incomes in country j in year i be $v_{i,j}$. In this paper, the Fourier function is used for fitting, and the relationship between the mineral output value $v_{i,j}$ and $y_{i,j}$ can be expressed as:

$$y_{i,j} = a_{0,j} + \sum_{n=1}^{\infty}\left(a_{n,j}\cos\left(\frac{2n\pi}{T}v_{ij}\right) + b_{n,j}\sin\left(\frac{2n\pi}{T}v_{ij}\right)\right) \tag{20}$$

According to the assumption that the impact of the asteroid mineral output value on GDP is the same as the impact of the earth's mineral output value, the final calculation formula of the GDP of country j in the i-th year is:

$$y_{i,j} = a_{0,j} + \sum_{n=1}^{\infty} a_{n,j}\cos\left(\frac{2n\pi}{T}(v_{ij} + v'_{i,j})\right) + \sum_{n=1}^{\infty} b_{n,j}\sin\left(\frac{2n\pi}{T}(v_{ij} + v'_{i,j})\right) \tag{21}$$

where $v'_{i,j}$ is the asteroid mineral output value of country j in year i.
Regarding the asteroid mineral output value $v'_{i,j}$ of country j in year i. Inquiring about relevant information, we know that the "Dragonfly" probe takes about $2-4$ years to collect samples from the selected asteroid to the earth, and about $27.21-68.04\ kg$ of samples can be brought back in one collection [10].
If all the samples brought back are platinum, then the calculation formula of the asteroid mineral output value of country j in the i-th year $v'_{i,j}$is as follows:

$$v_i = \frac{28\times1500\times68.04\times100}{2} \times m_i \times R^i \tag{22}$$

where m_i is the total number of probes in the four countries with asteroid mining technology in the i-th year, and R^i is the final mineral resource allocation ratio. m_i can be predicted by the ARIMA model based on the number of detectors in previous years.

3.3. Modelling of the Impact of Mining Strategies on Global Equity

According to the collected data of 2010 − 2019 countries' gross mineral production and GDP, the Fourier curve fitting was performed, and the fitting result of the United States was shown in Fig.4.

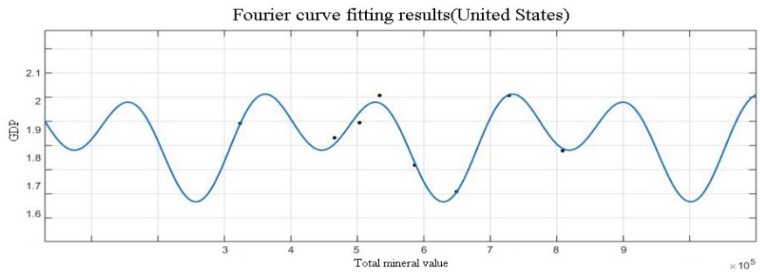


Figure 4. Fourier curve fitting curve (United States)

From Fig.4, it can be seen from the residual graph below that the residual of the data is relatively close to the zero point, indicating that the Fourier curve fitting can better match the original data. At this time, the fitted $R^2 = 0.831$ is relatively close to 1, and it can be seen that the Fourier curve fitting effect is very good.

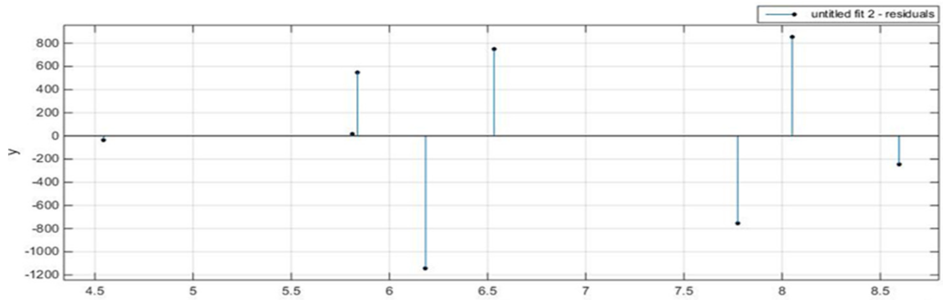


Figure 5. Fourier curve fitting residuals

The data of the relevant indicators in the next fifteen years are forecasted by the data of each country from 2010 to 2019, and the forecast data for 2023 is shown in Fig.5.

Taking the US high-tech export forecast as an example, the results of the ARIMA model are analyzed and tested. Using ADF and KPSS test to test the stationarity of the original data, after the first-order difference verification, the time series is stationary, so $d = 1$. Through the autocorrelation function and the partial autocorrelation function, $p = 3$ and $q = 1$ are determined, which is shown in Fig.6.

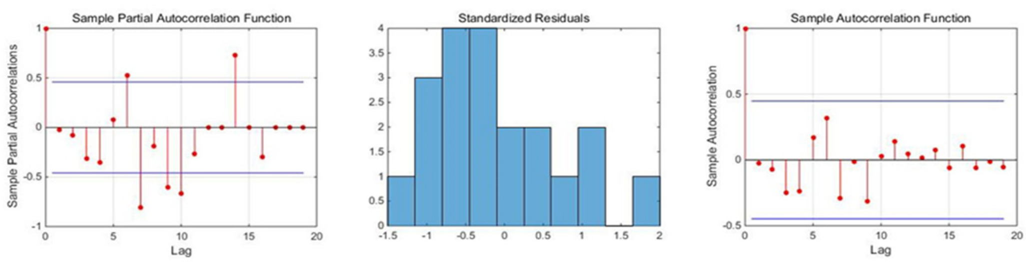


Figure 6. Result plot of residuals test

From Fig.6, it can be seen that the standard residuals are close to a normal distribution and there is no first-order correlation between the residuals. The above residual test can prove that the residuals are close to normal distribution and independent of each other. Therefore, the ARIMA(3,1,1) model can be considered reasonable.

4. Sensitivity Analysis

The entropy weight method is an objective assignment method to determine the index weight. Regarding the sensitivity of the entropy weight method, this paper analyzes the influence of the number of samples on the weight determination of the entropy weight method. Here we choose to study the weights of 5 indicators related to resource allocation in the global equity measurement model [11]. First, find the maximum and minimum values of each indicator in the existing data. Next, randomly generate 1000 sets of data in between. Finally, start from one sample and add one sample at a time to calculate the weight of each indicator. Among them, the weight change of GDP is shown in Fig.7.

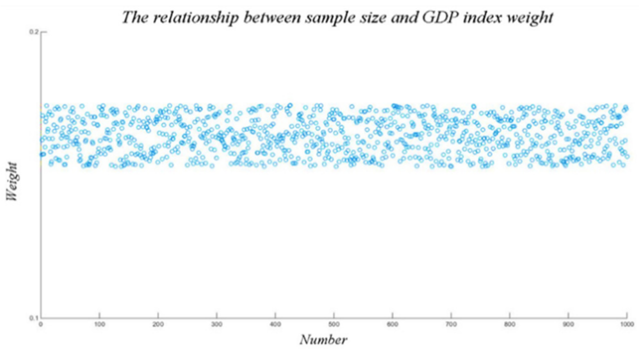


Figure 7. Scatter plot of weight change in GDP

We found that while keeping the indicator range unchanged, as the number of samples increases, the value of the weight fluctuates around a central value. Therefore, under the condition that the range of each indicator remains unchanged, as the number of samples increases, the weight changes less, that is, the weight is less affected by the number of samples. Therefore, we believe that the global equity measurement model has some stability.

5. Conclusion

We use the entropy method to determine the weight of the indicators according to the degree of change of each indicator value. In addition, the inputs and outputs of 15 countries in the next 15 years are forecasted using ARIMA model and Fourier series fitting. According to the forecast results, the global stock indexes under mining and non-mining conditions are 75.33% and 74.00% respectively, and it is found that mining has a promoting effect on global stocks, through research, it is found that when 60% of the mining revenue of non-mining countries is used to compensate mining countries, the global equity index is the best, and the global equity index is 76.00%.

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