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Resource evaluation and prediction model based on asteroid mining

Yueting Sun[1], Yan Liang[2], Xiangxi Xu[2]

[1]*School of Mathematics and Statistics, Beijing Technology and Business University, Beijing, 102488 China*
[2]*School of Economics, Beijing Technology and Business University, Beijing, 102488 China*

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Abstract: With the progress and innovation of global science and technology, countries have strengthened their in-depth exploration of the unknown field of outer space. Based on the current demand for fair access to outer space resources all over the world, this paper first constructs the global equity evaluation model based on the factor set of the global equity evaluation system, establishes the evaluation model by using analytic hierarchy process, and calculates the weight coefficient of each index in evaluating the competitiveness of asteroid mining; Next, the regression model is established based on the panel data. Finally, the asteroid mining prediction model based on ARMA is established to provide a certain basis for the state to specify relevant policies. The research completed in this paper can provide positive guidance for the realization of global equity in the field of outer space.

1. Introduction

With regard to the use of outer space, most countries in the world have reached a consensus that outer space resources should be the welfare and interest of all countries. With the progress and innovation of global science and technology, countries have strengthened their in-depth exploration of the unknown field of outer space. The ability of all countries to acquire and use outer space resources has been continuously improved, but it is followed by interest driven and human greed. The once fair international commitment has been impacted. Therefore, the maintenance of global equity at this time urgently needs to be achieved through reasonable policy assistance. How to reasonably allocate and make the most efficient use of shared outer space resources deserves the attention and feasible suggestions of the United Nations, governments and every individual citizen. Based on the basic needs of global equity maintenance, the main task of this paper is to establish a set of models to measure global equity, and determine the impact of asteroid mining on global equity through our global equity model.

2. Data preprocessing

All indexes mentioned in this paper are relative values; The scores referred to are the criteria for measuring the quality of indicators; The shared interests referred to are temporarily limited to outer space resources (asteroid mineral resources); The data mainly select indicators such as average income, total population, bank capital asset ratio, gap between the rich and the poor, employment rate, national development index, human capital index, per capita carbon emission and carbon dioxide injury cost as the basis for measuring global equity; In order to better reflect the changes of indicators over time, the data of recent five years are selected in data selection, and individual missing data are estimated by interpolation and fitting method.

3. Global equity evaluation model

3.1 Construction of evaluation system

This paper uses analytic hierarchy process to establish the global equity evaluation model and calculate the weight coefficient of each index in the global equity evaluation model. Each index is converted into the score of the hundred mark system and weighted with the weight coefficient to obtain the score of social equity. Determining the set of factors in the global Equity Evaluation Model. The global Equity Evaluation Model is evaluated from three aspects, namely, U is composed of three factor subsets:social distribution,human development,carbon emission,The subset factors are as follows:U1={capita income,population size,bank captal to assets,gap of wealth}; U2={employment,human development index,human captal index };U3={carbon emission per capita,save carbon dioxide damage };

3.2 Calculation process of analytic hierarchy process

Determine the weight of each factor, establish the judgment matrix of criterion layer B and the weight of each factor. The factors in the fuzzy comprehensive evaluation result vector B are compared in pairs according to experience, the scale method is introduced into the analytic hierarchy process, and the weights are further calculated by the judgment matrix. The judgment matrix A of global equity system evaluation is shown in Table 1.

Table 1 Global equity system assessment judgment matrix A

A	B_1	B_2	B_3	weight(W)
B_1	1	3	2	$W_{B_1} = 0.5391$
B_2	1/3	1	1/2	$W_{B_2} = 0.1642$
B_3	1/2	2	1	$W_{B_3} = 0.2967$

The consistency test is carried out, and the deviation consistency index of social equity evaluation model evaluation matrix A is obtained:

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

According to the random consistency ratio, the value of RI refers to the average consistency random index:

$$CR = \frac{CI}{RI} \tag{2}$$

$\lambda_{\max} = 3.009, CI = 0.005, RI = 0.56, CR = 0.009 < 0.1$, that is, the judgment matrix is considered to have consistency. The statistical table of random indicators of average consistency is shown in Table 2

Table 2 Statistical table of random indicators of average consistency

1	2	3	4	5	6	7	8	9
0.00	0.00	0.52	0.89	1.12	1.26	1.36	1.41	1.46

Establish the judgment matrix of each factor in the index layer and determine the weight. According to the above algorithm, the judgment matrix of the index layer to the criterion layer is calculated through table 2, and the weight of the judgment matrix is obtained, as shown in table 3-table 5.

Table 3 Judgment of index layer relative to criterion layer

B_1	B_{11}	B_{12}	B_{13}	B_{14}	weight(W)
B_{11}	1	1/3	4	2	$W_{B_{11}} = 0.3182$
B_{12}	3	1	7	2	$W_{B_{12}} = 0.4397$
B_{13}	1/4	1/7	1	1/2	$W_{B_{13}} = 0.0632$
B_{14}	1/2	1/2	2	1	$W_{B_{14}} = 0.1789$
$\lambda_{\max} = 4.3825, CI = 0.0573, RI = 0.87, CR = 0.0659 < 0.1$					

Table 4 Judgment matrix of relative index layer B_2

B_2	B_{21}	B_{22}	B_{23}	weight(W)
B_{21}	1	5	7	$W_{B_{21}} = 0.7235$
B_{22}	1/5	1	3	$W_{B_{22}} = 0.1932$
B_{23}	1/7	1/3	1	$W_{B_{23}} = 0.0833$
$\lambda_{\max} = 3.0659, CI = 0.0329, RI = 0.52, CR = 0.0633 < 0.1$				

Table 5 Judgment matrix of relative index layer B_3

B_3	B_{31}	B_{32}	weight (W)
B_{31}	1	3	$W_{B_{31}} = 0.7500$
B_{32}	1/3	1	$W_{B_{32}} = 0.2500$
$\lambda_{\max} = 2.0000, CI = 0.0000, RI = 0.00, CR = 0.0000 < 0.1$			

According to the analysis of tables 3 to 5, the consistency index CR of each judgment matrix is less than 0.1. By analyzing the judgment matrix, the consistency of the matrix can be obtained. According to the judgment matrix shown in Tables 2 to 5, calculate the combined weight of each evaluation factor on target layer a, and obtain the combined weight of index layer on target layer:

$$W = [0.1715, 0.2371, 0.0341, 0.0964, 0.11880, 0.0317, 0.0137, 0.2226, 0.0742]$$

Table 6 Combination weight of indicator layer relative to target layer

Evaluation content	weight	evaluating indicator	weight	Combined weight (W)
Social distribution	0.5391	average income	0.3182	0.1715
		Total population	0.4397	0.2371
		Bank capital asset ratio	0.0632	0.0341
		poverty gap	0.1789	0.0964
Human development	0.1642	rate of employment	0.7235	0.1188
		National Development Index	0.1932	0.0317
		Human capital index	0.0833	0.0137
Carbon dioxide emission rights	0.2969	Per capita carbon emissions	0.7500	0.2226
		Carbon dioxide injury cost	0.2500	0.0742

Convert data to corresponding scores. According to the data we collected, it is listed from the perspective of country and time. Find an eigenvalue in all data, such as the maximum value. Then assign a value to the characteristic data, and other data are weighted and converted into scores according to the actual proportion of the characteristic data. By weighting each indicator I, the score h of global equity is: $H_i = \sum(D_i \times W)$

3.3 Comprehensive score analysis of global equity

The comprehensive score of the global equity evaluation model is shown in Figure 1. Based on the world economic development level, scientific and technological innovation ability, humanities, resource possession and other factors and the selected corresponding indicators, the six countries are divided into three levels. Among them, the United States is in the first class; China, Japan and Russia are in the second class; India and Vietnam are in the third class; According to the global equity evaluation model established by us, countries around the world can measure the ability to obtain common interests and social responsibility corresponding to the comprehensive strength of each country, so as to achieve the equivalence between the income and the comprehensive strength of the country. The higher the distribution coefficient of countries with strong ability, the greater the distributed interests, so as to achieve vertical equity. On the other hand, as shown in the figure, countries in their own class can achieve a kind of relative fairness within the class. The world fair distribution coefficient fluctuates up and down within a certain range within the class, and the coefficient gap among countries within the class is not large. So as to achieve horizontal fairness.

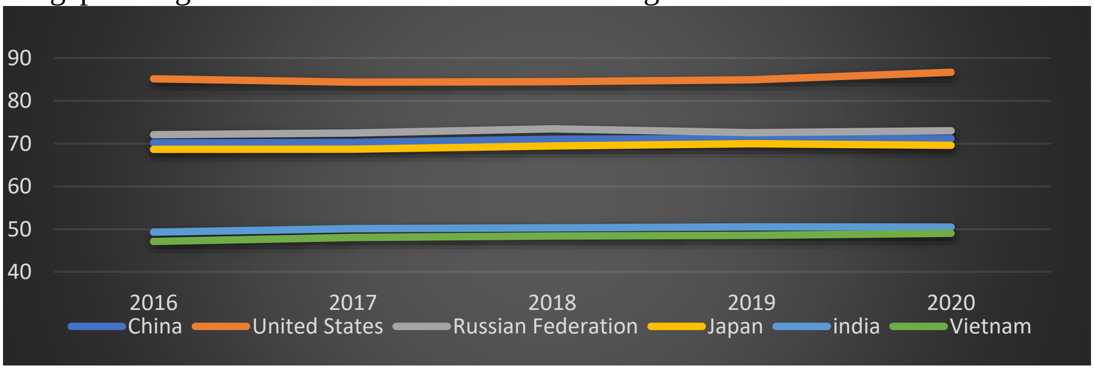

Figure 1 comprehensive score of global equity evaluation model

4. Asteroid mining competitiveness score

The analytic hierarchy process is used to establish the evaluation model and calculate the weight coefficient of each index in evaluating the competitiveness of asteroid mining. The scores of the national asteroid mining competitiveness model are obtained by converting each index into the score of the percentile system and weighted with the weight coefficient. Determine the factor set of competitiveness system.

The competitiveness is evaluated from three aspects, capital, manpower, technology, The establishment steps of the evaluation model are the same as those of the global equity evaluation model, which will not be repeated here. The global distribution evaluation model score obtained after determining the weight of each factor is shown in Figure 2.

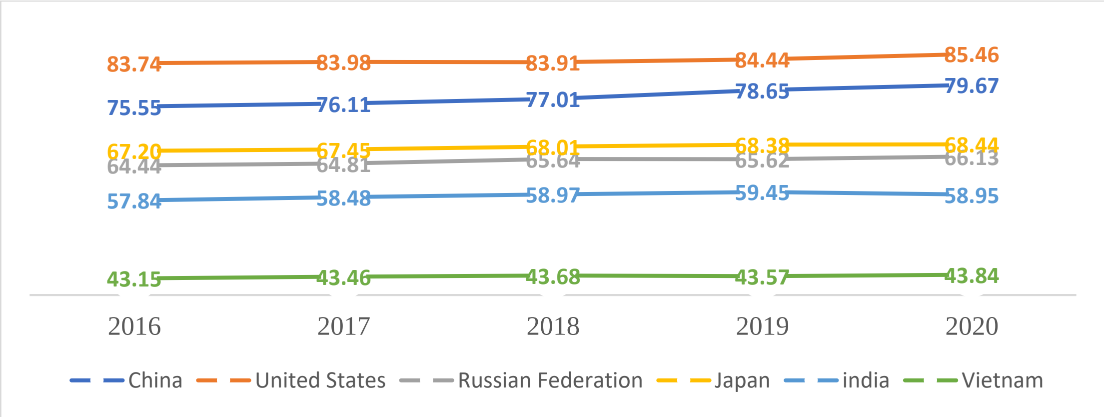

Figure 2 Adjusted new balance of the impact of asteroid mining on global equity

5. Panel data regression model

5.1 Establishment of regression model

After the technology of asteroid mining industry is mature, there will be countries that mainly invest in mining, countries that mainly implement mining and countries that rely on imported minerals. Countries that mainly rely on mining can be compared to today's resource-based countries. The study of the impact of mineral resources on the economic growth of resource-based countries is the same as the study of the impact of asteroid resources on the economic growth of countries mainly dependent on mining. We can predict the situation of the latter according to the conclusion of the former. Establish a panel data regression model, take GDP at different times as the dependent variable to measure the current economic situation, and take the richness of mineral resources, capital accumulation, industrialization, export trade development and infrastructure development as the independent variables of the panel regression model. The general form of panel data regression model is as follows:

$$Y_i = X_i \beta_i + U_i (i = 1, 2, 3, ..., N) \tag{3}$$

$$Y_i = \begin{bmatrix} y_{i1} \\ y_{i2} \\ \vdots \\ y_{it} \end{bmatrix}_{T\times 1}, \quad X_i = \begin{bmatrix} X_{1i1} & X_{2i1}\cdots & X_{ki1} \\ X_{1i2} & X_{2i2}\cdots & X_{ki2} \\ \vdots & \vdots & \vdots \\ X_{1iT} & X_{2iT} & X_{kiT} \end{bmatrix}_{T\times k} \tag{4}$$

$$\beta_i = \begin{bmatrix} \beta_{i1} \\ \beta_{i2} \\ \vdots \\ \beta_{iT} \end{bmatrix}_{k1}, \quad U_i = \begin{bmatrix} \mu_{i1} \\ \mu_{i2} \\ \vdots \\ \mu_{iT} \end{bmatrix}_{T1} \tag{5}$$

In the formula, K represents each country, T represents the total year of the data, Y0 is the initial GDP of each country, and YT is the final GDP of each country after t years. Explained variable$Y_t^k = \ln(Y_t^k / Y_{t-1}^k)$ represents the economic growth rate of each country, M is the mineral resource richness of each country, and other influencing factors affecting the national economic growth rate include capital accumulation, infrastructure development, export trade development and industrialization degree, which are represented by cap (capital accumulation), inf (infrastructure development), exp (export trade development) and ind (industrialization degree) respectively. After making the choice of random effect and fixed effect model, prob = 0.001 < 0.05, so reject the original hypothesis and adopt the fixed effect model. After F-test, F value = 3.18 > F0 01 = 2.137, so reject the original hypothesis and establish an individual fixed effect model. According to the above two tests, we can analyze that the GDP growth rate of each country is not only affected by the explanatory variables in this model, but also affected by many other factors, such as geographical location, history and so on. Therefore, the constant terms calculated by each country are different and not random.

5.2 Model solution

(1) Long term regression data from 1990 to 2010

Using eviews7 0 panel regression analysis of GDP and five influencing factors of each country. Through the above test, it is finally determined that the fitting effect of individual fixed effect model is the best. The results are shown in Table 7.

Table 7 fitting results of panel data regression model

Variable	Coefficient	t-Statistic	Prob.
C	-0.061	-0.947	0.312
LN(Y_t)	-0.001	-0.112	0.911
M	-0.465	4.338	0.000
Cap	0.169	7.24	0.000
Inf	0.318	0.581	0.162
Exp	0.579	4.502	0.000
Ind	0.201	3.510	0.001

According to the fitting results of the regression model, it can be seen that the mineral resources coefficient is negative, indicating the expansion of the amount of investment in the mining industry, but the country's GDP is reduced. It shows that the development mainly depends on the mining industry, which restricts the capital from entering manufacturing and other fields, resulting in the reduction of economic growth. The coefficients of capital accumulation, industrialization degree and export trade development are positive, indicating that these factors have a positive impact on national economic growth. Among them, the significance of infrastructure development to economic growth is not significant, which can only barely pass the significance of 0.15 The coefficient sign of initial GDP is negative, indicating that the economy as a whole has a convergence trend, but the significance is too poor. Therefore, the explanatory variable of initial GDP is eliminated and re regressed again. It is found that the overall significance is improved, but the coefficient symbols remain unchanged.

(2) Short term return from 2005 to 2010

Compared with 1990, the level of global industrialization in 2005 continued to improve, while the demand for industrialization also continued to rise. And with the increasing price of mineral resources, the value of mineral resources for countries rich in mineral resources is also increasing. Therefore, this paper makes another short-term return from 2005 to 2010.

Table 8 short term regression results

Variable	Coefficient	t-Statistic	Prob.
C	0.689	6.210	0.005
Y_t^*	-0.089	-5.119	0.000
M	-0.005	-1.001	0.273
Cap	0.301	1.232	0.232
Inf	3.361	5.468	0.000
Exp	0.289	8.601	0.000
Ind	0.061	0.691	0.524

From the short-term regression results, we found that the value of R correlation coefficient decreased and significantly decreased. It shows that the phenomenon of "resource curse" is not obvious in the short term. The possibility of this reason is that in the short term, the sale and export of mineral resources have brought great wealth to resource-based countries, which makes the industry of resource-based countries single. However, the consequences can not be clearly reflected in the short term. When this state is maintained for a long time, once the price of mineral resources falls or new mining competitors appear, it will cause heavy economic damage to resource-based countries. Therefore, we can see that once a country depends on a single industry to obtain wealth, it will fall into the trap of "resource curse". Because relying on the great abundance of resources can improve the economic growth rate in the short term. But it is very disadvantageous to long - term economic development

6. Asteroid mining prediction model based on ARMA

6.1 Establishment of RMA model

Based on the data from 2016 to 2020, a prediction model for five years after asteroid mining based on the above policy background is established to prove the effectiveness of our policy. Establish ARMA prediction model, take the observed values at different times as time series, explore the regression relationship between each evaluation index and the prediction object, and predict its change trend.

Considering the impact of each evaluation index and the change law of the prediction object itself, the ARMA model can be expressed as:Among them, and are regression coefficient and moving average coefficient respectively, which reflect the correlation of error terms in different periods.According to different conditions, there are two special cases.When q = 0, ARMA (P, q) model degenerates to AR (P), that is, regression model, it can be recorded as when p = 0, ARMA (P, q) model degenerates to MA (q), that is, moving average model, and the expression is

Taking the scores of the US global distribution model and evaluation indicators from 2016 to 2020 as samples, and the historical data of the previous five years as the observed value sequence, the model is constructed. Through the solution of the prediction model, we conclude that the score of the global distribution model is mainly affected by factors such as average income, total population, bank capital asset ratio, gap between the rich and the poor, employment rate, national development index, human capital index, per capita carbon emission, carbon dioxide injury cost and so on. Therefore, we mainly analyze the impact of the above aspects on global distribution.

Under the specific social conditions of the United States, after the mining of small and medium-sized planets in the prediction model. We use the model to predict the change of global distribution model score in five years. As we expected, asteroid mining will bring new opportunities and risks to the United States.

6.2 Model solution analysis and evaluation

According to the existing data, the above results and models are obtained by multiple measurements to reduce errors (certain errors are difficult to avoid and the overall trend remains unchanged). The United States we explored is a developed country, which has a stable and slight increase in many data after asteroid mining. Among them, labor forc, GDP, higher education and other factors are more closely related to the global equity system. Therefore, the United States can improve their scores by implementing policies related to the above factors. The actual situation of the United States is a good market. It is easier to make efforts on the factors related to the high score of the global distribution model, so policymakers need to judge and choose among various factors.

Table 9 Prediction Table of new System in United States from 2021 to 2025

The forecast	capita income	carbon emission per	GDP	higher education	human developme	Employment	population size	labour force	gap of wealth	so on	all
2021	6.66	5.18	14.42	13.41	7.40	2.69	5.25	17.48	6.71	6.41	85.61
2022	6.69	5.18	14.38	13.36	7.33	2.63	5.24	17.45	6.72	6.40	85.38
2023	6.73	5.15	14.43	13.35	7.39	2.66	5.26	17.46	6.68	6.40	85.51
2024	6.91	5.32	14.43	13.40	7.54	2.80	5.31	17.52	6.80	6.53	86.56
2025	7.00	5.42	14.50	13.45	7.55	2.84	5.31	17.58	6.83	6.55	87.03
The forecast after the policy change											
2021	6.66	5.18	14.48	13.41	7.41	2.71	5.25	17.48	6.69	6.41	85.68
2022	6.71	5.18	14.44	13.36	7.34	2.65	5.24	17.45	6.74	6.40	85.51
2023	6.75	5.15	14.50	13.35	7.41	2.68	5.26	17.46	6.70	6.42	85.68
2024	6.93	5.32	14.50	13.40	7.56	2.83	5.32	17.56	6.82	6.55	86.79
2025	7.02	5.42	14.57	13.47	7.58	2.87	5.32	17.62	6.85	6.58	87.30

As shown in the table, the policies adopted in 2021 encourage all countries to carry out orderly commercial development of asteroid mineral resources, and give financial support and scientific and technological support to the countries that are the first to study and try. In order to promote the development of asteroid mining industry and benefit the whole mankind, GDP score increased by 0.06, human development score increased by 0.01, employment score increased by 0.02 and gap of wealth score decreased by 0.02.

The policy adopted in 2022 has formulated clear international legal system to deal with the provisions of the procedures for mining, excavating or moving asteroid resources, and made legal agreements on how to distribute the benefits obtained in the development and production of such resources, resulting in an increase of 0.02 in capita income and 0.04 in gap of wealth.

The policies expected to be adopted in 2023 will strictly supervise the asteroid mining industry, and countries with mature technology should bear corresponding international responsibilities. For the obtained minerals, the tax in equal proportion shall be paid according to the actual value, which will be used to help other countries develop asteroid mining technology. GDP increased by 0.01, human development increased by 0.01 and so on increased by 0.02.

The policies expected to be implemented in 2024 encourage the flow of skilled population, reduce the immigration threshold, increase the number of social migrants, and realize the blue collar of immigrants, resulting in an increase of 0.01 in employment and 0.01 in population size.

The policies expected to be implemented in 2025 encourage scientific research, develop relevant professional education, and establish corresponding scientific research institutions or funds, which will increase higher education by 0.01, human development by 0.01 and so on by 0.02.

It can be seen that under the implementation of the measures, the score of the global distribution model of the United States has increased. Therefore, the policies adopted from 2021 to 2025 can effectively improve the score of the model, which are relatively effective. However, the relative effect is also different. Relatively changing GDP and higher education score more for the global distribution model.

7. Conclusion

In view of the current use of outer space, this paper needs to analyze the current global equity system and complete the establishment of relevant models. Firstly, the global equity evaluation model is constructed based on the factor set of the global equity evaluation system, the evaluation model is established by using analytic hierarchy process, the weight coefficient of each index in evaluating the competitiveness of asteroid mining is calculated, and the comprehensive score summary of the global equity evaluation model is completed; Next, complete the establishment of regression model based on panel data and conduct long-term and short-term analysis, summarize the trap of "resource curse" through data analysis, and finally establish an asteroid mining prediction model based on ARMA. Taking the mining development of the United States as an example, collect a number of data after asteroid mining in the United States for analysis, so as to provide a certain basis for the country to specify relevant policies. The research completed in this paper can provide positive guidance for the realization of global equity in the field of outer space. In the follow-up research, this paper will further optimize the model through model modification and data collection.

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