Research on Operation Performance Evaluation of Listed Mining Enterprises in Jiangxi Province Based on DEA-BCC Model

Jun-hua Hou\textsuperscript{a,b}; Xiao-di Zhang\textsuperscript{b,*}; Zhen Feng\textsuperscript{b}

\textsuperscript{a} Research Center of Resource and Environment Strategies, East China University of Technology, Fuzhou 344000, China
\textsuperscript{b} College of Economic and Management, East China University of Technology, Nanchang Jiangxi 330013, China
\textsuperscript{*} Corresponding author at: College of Economic and Management, East China University of Technology, Nanchang Jiangxi 330013, China

E-mail address: \textsuperscript{a}jhou@ecut.edu.cn, \textsuperscript{b,*}760656075@qq.com

Abstract: In the new economic environment, in order to further expand and strengthen the local mining industry and realize the sustainable development of geological and mineral resources, it is necessary to effectively transform the advantages of geological and mineral resources into industrial and economic advantages with scientific operation performance management. Based on this, this paper constructs a DEA-BCC model for performance evaluation of geological and mining enterprises in Jiangxi province, and conducts evaluation and research on the operational performance of geological and mining enterprises in Jiangxi Province. The research shows that in recent years, the mining enterprises in Jiangxi province have been developing well on the whole. However, some enterprises have too small scale and poor production efficiency, so they should strengthen cost control, appropriately expand scale, pay attention to scientific and technological innovation development, and improve the quality of employees to improve the level of business performance.

1. Introduction
Jiangxi province is rich in geological resources. The analysis of the proven mineral reserves shows that 33 kinds of geological resources rank among the top five in China, and 100 kinds of minerals have been utilized, making It the world capital of tungsten, porcelain, copper, lithium, rare earth kingdom and China's important mining bases of uranium, gold, and silver.

With the increasing exhaustion of geological resources and the increasing demand for geological resources due to the rapid economic development, Jiangxi province began to strengthen the management of geological resources development, based on the concept of sustainable development, increase the adjustment of industrial structure, promote the transformation and upgrading of local mining industry. In the field of related research of geological and mineral resources enterprises, strengthening the research of operational performance evaluation is of profound practical significance to the sustainable development of provincial geological and mineral resources enterprises, whether it is for the geological and mineral enterprise groups that are moving towards internationalization and have international competitiveness or for small and medium-sized geological and mineral resources
enterprises. Based on the selected five geological mining resources of listed companies in Jiangxi province in 2014-2019 based on the relevant data, using DEA method to evaluate operating performance of these enterprises, and horizontal comparison, which can help in Jiangxi province, geological mining resources companies understand the problem itself, and for better development of countermeasures according to their own situation.

2. Literature Review
In recent years, DEA method has been favored by scholars and used by a large number of scholars at home and abroad, and the research on performance management in energy, ecology, science and technology has been increasing gradually. Y. ba-gutierrez et al. (2009) attempted to use DEA to analyze ecological performance efficiency from the perspective of input and output. Ta-wet PAN et al. (2010) described the scientific and technological performance of innovation system (NIS) in 33 Asian and European countries, and found that the performance of Asian countries was generally better than that of European countries through DEA evaluation. Liu Xueqin et al. (2014) studied the business performance of photovoltaic enterprises with DEA method in renewable energy. Jin Hongchun and Cao Fangping (2016) used DEA method to evaluate the financial performance of environmentally-friendly listed companies from multiple perspectives by collecting their financial information. Lin Peijun (2020) used the BCC-DEA model in factor analysis and data envelopment analysis to evaluate the performance of China’s A-share listed coal enterprises, compared and analyzed their operating performance, and found out the reasons for the ineffective implementation.

Traditional performance evaluation methods do not take into account the whole process of evaluation and cannot objectively and accurately reflect the actual operating performance of enterprises. Meanwhile, the current practical research on performance evaluation of geological and mineral enterprises is not sufficient and lacks a unified and standard definition. Therefore this article uses the data envelopment analysis (DEA) method in the BCC-DEA model to measure the operating performance of the enterprise, in order to help the business operators to analyze the achievements in the process of operation and existing problems of performance management decisions for the enterprise to provide valuable information, at the same time, also help the government departments have a thorough understanding of geological mining industry management, provide decision-making useful information.

3. Research Design

3.1 Selection of evaluation indexes
The selection of variables in the index system is mainly based on the operating cost, enterprise scale, asset input and specific evaluation needs of geological and mining enterprises. The selection principle of the above indexes determines that the selection of the index system is limited. In order to meet the specific requirements of DEA method, 6 indexes are selected as the input and output indexes.

The input index of total assets, its amount, increase and decrease reflect the resource allocation, scale and future development trend of the mining enterprises. Most of the employees are ordinary workers and technicians, who are the creators of the economic interests of enterprises. As an input index, they can fully reflect the level of performance management. The reason why the management cost is taken as the input index is that the managers of geological and mining enterprises use this index to analyze the management efficiency. In addition, the main business cost is used as the input index, and the cost control level of the enterprise will directly affect its profitability. Among the output indicators, net profit is the after-tax profit obtained by mining enterprises, the basis for operation and management decisions, as well as the basis and source for investors and creditors to obtain income, which is a key indicator for sustainable development of mining enterprises. The main business income as an output index can clearly reflect the development status of mining enterprises, capital turnover and other conditions.
3.2 Selection of evaluation objects

Traditional mining enterprises mainly provide prospecting services. In order to better realize the rational allocation of resources, assets and capital, mining enterprises begin to transform to comprehensive management directions such as prospecting, mining, dressing, smelting and trade. Geological exploration service, asset management and capital management are the three stages in the development process of geological and mineral enterprises, among which capital management is the ultimate goal of sustainable development of geological and mineral enterprises[6]. Based on this idea, this paper selects the A-share listed geological and mineral resources enterprises in Jiangxi Province as the research samples. Based on the summary of Listed Companies with Mineral Resources in 2019, Jiangxi Copper, Zhangyuan Tungsten, Fangda Special Steel, Anyuan Coal and New Steel are selected as listed mining enterprises.

4. Empirical Analysis

4.1 Data Sources

Based on the data envelopment analysis model and using the DEA-BCC model to measure the performance of enterprises, the data from 2014 to 2019 are selected as sample data. The relevant data are from Jiangxi Statistical Yearbook, RESSET database and Oriental Fortune Net. The data sources are relatively reliable and objective, which can ensure the accuracy of the conclusions to a certain extent. The original data of 2014-2019 annual indicators are shown in Table 1:

| Year | The name of the company | The number of employee | Main business cost | Total assets | Management fees | Net profit | Main business income |
|------|-------------------------|------------------------|-------------------|-------------|----------------|------------|---------------------|
| 2014 | Jiangxi Copper          | 21366                  | 1922249           | 9532373.49  | 18461.8       | 28495.6    | 1988334.9          |
|      | Fangda Special Steel    | 8756                   | 975055.31         | 937210.42   | 64396.82      | 59296.16   | 1156603.36         |
|      | Anyuan Coal             | 25947                  | 984516.42         | 922149.04   | 31530.83      | 7021.6     | 1065164.4          |
|      | New Steel               | 20648                  | 3003032.62        | 3049536.94  | 91860.52      | 42813.6    | 3237029.49         |
|      | ZhangYuan Tungsten      | 3380                   | 165339.07         | 316512.31   | 14526.26      | 6511.68    | 203882.94          |
|      | Jiangxi Copper          | 20873                  | 1814782.6         | 8975521.11  | 202645        | 68475.5    | 185782.49          |
|      | Fangda Special Steel    | 8128                   | 719861.65         | 930572.89   | 48798.97      | 11468.4    | 814829.06          |
| 2015 | Anyuan Coal             | 14147                  | 462821.96         | 1039291.83  | 21635.05      | 218.96     | 512204.01          |
|      | New Steel               | 19466                  | 2450344.3         | 2822623.73  | 52682.27      | 5444.59    | 2537101.35         |
|      | ZhangYuan Tungsten      | 3498                   | 124089.52         | 312547.38   | 12730.73      | -15982.66  | 134383.73          |
|      | Jiangxi Copper          | 21489                  | 19531027          | 8748111.24  | 166967        | 93516.1    | 2023082.2          |
|      | Fangda Special Steel    | 7422                   | 717317.84         | 84770.76    | 58609.01      | 69416.49   | 892377.93          |
| 2016 | Anyuan Coal             | 9497                   | 291430.51         | 734516.36   | 18428.54      | -214334.9  | 326123.56          |
|      | New Steel               | 19363                  | 2851730.25        | 2927765.21  | 46457.41      | 50821.09   | 3046264.24         |
|      | ZhangYuan Tungsten      | 3369                   | 111209.87         | 331229.54   | 11408.93      | 4725.49    | 131138.93          |
|      | Jiangxi Copper          | 20880                  | 19568238          | 9746981.54  | 167572        | 171326.0   | 2050542.4          |
|      | Fangda Special Steel    | 7438                   | 947762.94         | 861469.8    | 81407.27      | 255023.3   | 1394474.96         |
| 2017 | Anyuan Coal             | 11761                  | 373885.9          | 707170.74   | 17674.77      | -71784.02  | 413016.79          |
|      | New Steel               | 18667                  | 4448722.69        | 3322592.94  | 23268.91      | 313941.1   | 4996701.35         |
|      | ZhangYuan Tungsten      | 3355                   | 150553.05         | 359766.9    | 10102.89      | 3148.8     | 183060.67          |
|      | Jiangxi Copper          | 19711                  | 20747187          | 10286582.7  | 155861.7      | 245431.7   | 2152898.7          |
|      | Fangda Special Steel    | 7362                   | 1160447.08        | 961776.16   | 165519.47     | 293197.8   | 1728585.09         |
| 2018 | Anyuan Coal             | 9179                   | 437686.43         | 665709.44   | 15289.12      | 6146.69    | 504865.57          |
|      | New Steel               | 18142                  | 4876822.98        | 4163575.6   | 31193.2       | 591325.87  | 5606330.20         |
|      | ZhangYuan Tungsten      | 3419                   | 152797            | 400479.79   | 9879.12       | 4800.78    | 186925.64          |
|      | Jiangxi Copper          | 23213                  | 2316769.0         | 1349139.54  | 179655.92     | 217839.0   | 2403630.4          |
|      | Fangda Special Steel    | 7480                   | 1159069.43        | 1294982.15  | 133534.01     | 171489.56  | 1538899.91         |
| 2019 | Anyuan Coal             | 9818                   | 503949.86         | 661220.86   | 17833.97      | 1172.56    | 555398.77          |
|      | New Steel               | 17738                  | 5271341.26        | 4516664.52  | 35383.59      | 342993.62  | 5790357.47         |
|      | ZhangYuan Tungsten      | 3552                   | 170468.73         | 368882.02   | 12204.40      | -29420.79  | 182779.967         |

4.2 Efficiency index of DEA-BCC model

According to the dimensionless normalization, the BCC model in DEAP2.1 software was used to
calculate the following efficiency indicators in the data table, as shown in Table 2:

| The name of the company | Year | Overall efficiency | Pure technical efficiency | The scale efficiency | Returns on scale increase or decrease |
|-------------------------|------|--------------------|---------------------------|----------------------|----------------------------------------|
| Jiangxi Copper          | 2014 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2015 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2016 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2017 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2018 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2019 | 1.000              | 1.000                     | 1.000                | -                                      |
| Fangda Special Steel    | 2014 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2015 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2016 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2017 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2018 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2019 | 1.000              | 1.000                     | 1.000                | -                                      |
| Anyuan Coal             | 2014 | 0.966              | 0.971                     | 0.994                | irs                                    |
|                         | 2015 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2016 | 0.302              | 0.619                     | 0.488                | irs                                    |
|                         | 2017 | 0.617              | 0.714                     | 0.864                | irs                                    |
|                         | 2018 | 0.843              | 0.897                     | 0.940                | irs                                    |
|                         | 2019 | 0.886              | 0.997                     | 0.889                | irs                                    |
| New Steel               | 2014 | 0.973              | 0.987                     | 0.986                | drs                                    |
|                         | 2015 | 0.988              | 0.988                     | 0.999                | drs                                    |
|                         | 2016 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2017 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2018 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2019 | 1.000              | 1.000                     | 1.000                | -                                      |
| ZhangYuan Tungsten      | 2014 | 1.000              | 1.000                     | 1.000                | -                                      |
|                         | 2015 | 0.831              | 1.000                     | 0.831                | irs                                    |
|                         | 2016 | 0.911              | 1.000                     | 0.911                | irs                                    |
|                         | 2017 | 0.767              | 1.000                     | 0.767                | irs                                    |
|                         | 2018 | 0.846              | 1.000                     | 0.846                | irs                                    |
|                         | 2019 | 0.666              | 1.000                     | 0.666                | irs                                    |

The efficiency indicators in Table 2 were averaged, and the following table 3 was obtained:

| The name of the company | Overall efficiency | Pure technical efficiency | The scale efficiency | Returns on scale increase or decrease |
|-------------------------|--------------------|---------------------------|----------------------|----------------------------------------|
| Jiangxi Copper          | 1.000              | 1.000                     | 1.000                | -                                      |
| Fangda Special Steel    | 1.000              | 1.000                     | 1.000                | -                                      |
| Anyuan Coal             | 0.769              | 0.866                     | 0.863                | irs                                    |
| New Steel               | 0.994              | 0.996                     | 0.998                | drs                                    |
| ZhangYuan Tungsten      | 0.837              | 1.000                     | 0.837                | irs                                    |
| The mean                | 0.92               | 0.972                     | 0.940                |                                        |
| The variance            | 0.0096             | 0.0028                    | 0.0054               |                                        |
4.3 Analysis and evaluation of DEA-BCC model

4.3.1 Overall efficiency analysis. The overall efficiency can clearly reflect the management level of an enterprise, especially the comprehensive evaluation and analysis of the evaluation unit in terms of scale allocation, technology level and resource utilization rate. As can be seen from Table 2, the overall efficiency, pure technical efficiency and scale efficiency of Jiangxi Copper and Fangda Special Steel all reach 1, indicating that these two listed enterprises are in the forefront of operation and management of geology and mineral enterprises in Jiangxi province, and their utilization of resources has reached the optimal state in terms of scale and technology. However, the overall efficiency of anyuan Coal, New Steel And Zhangyuan Tungsten Industry were all less than 1, and the actual output did not reach the maximum possible output, indicating that these enterprises did not make sufficient use of resources and may have some waste of resources.

4.3.2 Analysis of pure technical efficiency. Pure technical effectiveness analysis reflects the impact of management mechanism, operation level and technology level on enterprise operation efficiency. It can be seen from Table 3 that Jiangxi Copper, Fangda Special Steel and Zhangyuan Tungsten industry are technically effective, indicating that these three enterprises have a good level of internal management in the industry, and the whole industry is at an advanced level of technical management, which can effectively mobilize the output efficiency of enterprises. For the two companies whose pure technical efficiency is less than 1, they need to adjust their internal components, introduce advanced production equipment, improve their technical management level, and strengthen their technological development and innovation level.

4.3.3 Scale efficiency analysis. Scale efficiency reflects the state of production scale of listed mining enterprises. The scale efficiency of Jiangxi Copper And Fangda Special steel are both 1, which indicates that the scale efficiency is effective and the production scale has reached the maximum value and is now in the most appropriate state. Since 2016, New Steel has achieved scale efficiency and efficiency. However, the scale efficiency of Anyuan Coal industry and Zhangyuan Tungsten Industry is less than 1, which may be caused by the small production scale.

4.3.4 Return on scale analysis. The increase of scale returns is due to the improvement and expansion of output capacity, which leads to the reduction of the cost of geological and mineral products. The listed mining companies with increasing returns on scale among the evaluation objects include Anyuan Coal and Zhangyuan Tungsten industry, which need to continue to expand their scale to improve their competitiveness. The listed companies with constant scale income include Jiangxi Copper and Fangda Special Steel, whose current scale has reached the maximum production value and is the most reasonable. The listed enterprises with diminishing returns to scale are New Steel Shares, whose scale level keeps decreasing, mainly due to the large scale of underground mining and production, the uncoordinated phenomenon in the development process, and the production being affected, which leads to the decrease of efficiency. However, in the past four years, some measures have been taken to make the production scale of New Steel more reasonable.

5. Conclusions and Suggestions

5.1 Research Conclusion
The variance of overall efficiency of listed mining enterprises in Jiangxi province is 0.0096; The variance of pure technical efficiency is 0.0028; The variance of scale efficiency is 0.0054. This indicates that the efficiency difference within the whole industry is small, there is no significant difference between companies, and the operating performance of listed mining enterprises in Jiangxi province is also roughly the same. The following conclusions can be drawn from the longitudinal and longitudinal study:
1) DEA of Fangda Special Steel is relatively effective in Jiangxi copper industry. The study shows that the overall efficiency, pure technical efficiency and scale efficiency of the two enterprises are both 1, indicating that they have a high level of operational performance management and the production scale reaches the maximum production value. They are in the leading position in the field and mining enterprises in Jiangxi province. The development data of these two companies can be used for reference by other companies. Other companies should refer to these two best methods to analyze and improve the causes of inefficiency and unstable operation and make appropriate improvements.

2) DEA of Anyuan coal industry and Zhangyuan tungsten Industry is relatively ineffective, but the scale returns are increasing. Disadvantages, the operating performance of the two companies though AnYuan coal, ZhangYuan tungsten industry in scale efficiency increasing state, but from the results of the two companies overall efficiency, pure technical efficiency and scale efficiency are lacking, but can through improve production efficiency, the factors of production efficiency, to achieve a higher overall efficiency. Among them, the scale efficiency of Zhangyuan tungsten industry is ineffective and the pure technology scale is effective, which may be due to the imbalance of enterprise scale and input and output, leading to the failure of comprehensive technical efficiency.

3) From DEA invalid to relatively effective New Steel shares. In 2014-2015, the return on scale is decreasing and the scale is not economic. However, from 2016 to 2019, due to the adjustment of enterprise strategy, improvement of performance management and other measures, the operation performance level is gradually stable, and the overall efficiency, pure technical efficiency and scale efficiency finally reach 1. To sum up, the listed mining enterprises in Jiangxi province have been in good development from 2014 to 2019 and are in constant progress. The pure technical efficiency level of 0.972 is larger than the scale efficiency level of 0.940. Therefore, some enterprises that fail to realize the effectiveness are mostly due to the invalid enterprise size, and some are due to the ineffective pure technology, or it may be influenced by both factors.

5.2 Suggest
Based on the analysis of the comprehensive management performance efficiency of listed geological mining companies in Jiangxi Province, this paper puts forward the following Suggestions:

First, there is little difference in the number of listed mining enterprises in Jiangxi province at different stages of scale reward, and most of them are at an increasing stage. Therefore, they should appropriately expand their scale according to their own development status, pay attention to the standardization and adjustment of enterprise scale, and strive to achieve the optimization of the industry level. By drawing lessons from and learning from listed mining enterprises in the forefront of the industry, strengthening cost control and optimizing management scale, and then improving output efficiency, the overall operation efficiency can be improved and the return on scale can become effective.

Second, for the listed mining enterprises with ineffective pure technology, it is necessary to introduce advanced production equipment, so as to realize the progress of technical level. As for the whole mining enterprises, facing the pressure brought by the falling product price, they still need to keep innovating technologies to further improve the technological level of the industry in order to make profits. The future development of listed mining enterprises in Jiangxi province is to take the road of innovation, the goal of improving industrial concentration and the model of attaching importance to product quality. The investment of innovation factors in enterprises should be strengthened from the perspectives of industry level, geological and mineral resources, so as to improve its technical efficiency, scale efficiency and resource and environment utilization efficiency.

Third, the management level should improve the in-depth understanding of the sustainable development of geological and mineral resources, change the traditional concept of efficiency first, improve their own management level, and further optimize the investment and utilization efficiency, so as to improve the operational performance level of geological and mineral resources enterprises. The relevant departments of Jiangxi province shall establish a management system suitable for the
development of the geological and mining enterprises in order to promote the improvement of the operation performance of the geological and mining enterprises in Jiangxi province.

Fourth, increase the proportion of highly educated talents, improve the professional level of employees, pay attention to the quality of employees. The distribution of talents in geological and mining enterprises is larger, and there are often more low-level talents, while the talents with high experience and high technology are very rare. It is urgent for mining enterprises to formulate talent management plan, absorb more innovative talents, and give preferential treatment.

Acknowledgements
Thanks for the support of the key research base project of Humanities and Social Sciences JD1924 in Jiangxi Province and the Research Center of Resource and Environment Strategies, East China University of Technology.

Reference
[1] Barba-Gutierrez Y, Adenso-Diaz B, Lozano S. Eco-Efficiency of Electric and Electronic Appliances: A Data Envelopment Analysis (DEA) [J]. Environmental Modeling & Assessment, 2009, 14(4):439-447.
[2] Ta-wet Pan, Shiu-wan Hung, Wen-min Lu. DEA Performance Measurement of the National Innovation System in Asia and Europe [J]. Asia-Pacific Journal of Operational Research, 2010(27):369-392.
[3] Liu Xueqin, Wang Jianming, Chen Hongxi, et al. Research on The Business Performance Evaluation of Listed Companies based on DEA Model-Data from the Photovoltaic industry [J]. Finance and Accounting Newsletter, 2014(27): 44-46+129. (in Chinese)
[4] Jin Hongchun, Cao Fangping. Research on financial Performance Evaluation of Environmentally-friendly listed Companies based on DEA Method [J]. Economic Forum, 2016(02):64-71. (in Chinese)
[5] Peijun Lin. Research on the performance of listed coal enterprises based on BCC-DEA [J]. Commercial Accounting, 2020(03):66-71. (in Chinese)
[6] Zhou Songlin, Yang Xiao. China coal geology, 2014, 26(12):94-96. (in Chinese)