J Inf Process Syst, Vol.19, No.6, pp.713~721, December 2023
https://doi.org/10.3745/JIPS.04.0292

ISSN 1976-913X (Print)
ISSN 2092-805X (Electronic)

JOURNAL OF INFORMATION PROCESSING SYSTEMS JIPS

Research on Economic Performance of Mining Enterprises Based on Stakeholders

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Abstract
Conventional mining enterprises, particularly coal-related ones, exhibit substantial environmental pollution and high energy consumption, while those involved in new energy resources, such as lithium and cobalt, face severe resource shortages. Consequently, the economic efficiency of China's mining enterprises is significantly constrained. This study examines data from nine representative listed enterprises in China spanning 2016 to 2021. Employing the DEA model—i.e., BCC (VRS) model, we analyze the economic efficiency of mining enterprises with a focus on stakeholders. The paper provides static and dynamic analyses, offering insights and recommendations for enhancing technology, reducing costs, and fortifying social relationships.

Keywords
BCC (VRS) Model, DEA Model, Economic Performance, Mining, Stakeholders

1. Introduction

Mining enterprises, positioned at the upstream end of the industrial chain, exert a direct impact on downstream transportation and manufacturing industries [1]. They serve as the foundation for national economic development, with primary input factors including primary energy and raw materials. The development of these enterprises contributes to improved production efficiency and facilitates industrial upgrading [2]. In 2021, China's mining enterprises possessed total assets amounting to 130,349.9 billion Chinses yuan (CNY), comprising 399,375 enterprises, of which 286,430 were private [3]. As resource-based entities, with a significant proportion being profitable private enterprises, mining enterprises have shifted their primary risks from price fluctuations to environmental and regulatory risks, as indicated in KPMG's Global Mining Outlook 2022. The evolving general environment necessitates closer collaboration with stakeholders. This includes reinforcing ties with employees through increased investments in employee welfare and proactive tax payments to the government to mitigate regulatory risks, exemplifying corporate social responsibility [4]. Stakeholder engagement has progressively become a focal point for market participants.

Research on economic performance based on stakeholders dates back to 2005. Huang [5] utilized correlation analysis to evaluate the economic efficiency of nonferrous metals industry-listed companies, considering social relations. Chen [6], employing the expert scoring method and efficiency coefficient

Manuscript received November 22, 2022; first revision January 16, 2023; second revision February 13, 2023; accepted February 16, 2023.
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method, established five dimensions to assess the performance of mining enterprises encompassing economic, environmental, and social relations. Existing literature primarily analyzes enterprises' performance regarding responsibility to stakeholders. However, limited research incorporates stakeholders as input indicators to explore their impact on economic performance, particularly in the context of highly polluting mining enterprises. Consequently, this paper examines nine listed mining enterprises, applying data envelopment analysis (DEA) model [7-9] to investigate the influence of stakeholder indicators on economic performance output. The findings yield practical recommendations for enhancing overall enterprise economic performance.

2. Input-Output Analysis

2.1 Basic Assumptions

We posit two hypotheses.

Hypothesis 1: the economic performance of China's mining enterprises, when considering stakeholders, is low. Secondly, mineral resources are inherently unique. Upon depletion, the initial investment becomes unrecoverable, with evident sunk costs. Consequently, the economic performance of mining enterprises is influenced by technological innovation, enterprise management, and enterprise scale.

Hypothesis 2: The technical impact on the economic performance of mining enterprises is conspicuous [10-12].

2.2 Analysis of Investment in Mining Enterprises Based on Stakeholders

Stakeholder theory mainly examines social responsibility [13]. It delineates the focal points of social relations and offers insights into how these relations affect enterprise economic performance [14-16]. This paper focuses on stakeholders to study their impact on the economic performance of mining enterprises [17]. Given the distinctive industrial characteristics of mining enterprises and their involvement with numerous stakeholders, we choose stakeholders as the primary research focus.

Firstly, mineral resources form the bedrock of the national economy, supporting 70% of China's GDP and serving as critical strategic materials. Consequently, the country emerges as a significant stakeholder in mining enterprises. These enterprises manifest their social relations with the country through tax payments, measured by the book income tax rate (total income tax/total profits). A higher indicator signifies stronger social ties with the country.

Secondly, mineral resource development entails risks, necessitating safety investments in areas such as safety protection and management expenses. Safety costs are substantial, and ensuring employee safety and attracting technological talent are crucial avenues for mining enterprises to mitigate risks and enhance economic benefits. This aspect represents a primary social responsibility, measured by the employee welfare rate (cash paid for employees/cash outflow from operating activities). A higher proportion signifies better employee welfare.

Thirdly, the cost of mineral products in China is elevated, and mining enterprises, as resource-based entities, entail significant initial investments. For instance, the total profit of the mining industry in 20,221 amounted to approximately 1 trillion CNY, with a total investment reaching 1.1 trillion CNY. Shareholders, as primary contributors of funds, evaluate the company's value through earnings per share (average net profits/outstanding ordinary shares), thereby measuring the enterprise’s social relations with employees. Creditors, the secondary provider of funds, are expressed through the asset liability ratio (total liabilities/total assets).

Lastly, the relationships with customers and suppliers are gauged by the turnover rates of accounts receivable and accounts payable, respectively.

2.3 Economic Performance Output Analysis

Economic performance generally pertains to the production efficiency of an enterprise, specifically addressing how an enterprise can curtail production costs, institute economies of scale, and enhance production efficiency [18]. Key indicators for measuring economic performance encompass return on total assets, return on net assets, operating profit margin, among others. In this study, we opt for return on total assets as the benchmark for economic performance evaluation. Calculated as (total profit + interest expense)/average total assets, this metric encapsulates the overall outcome of an enterprise's asset utilization. A higher indicator signifies more effective utilization of assets.

2.4 Economic Performance Output Analysis

Data envelopment analysis is used to gauge economic efficiency, considering enterprises’ responsibility to stakeholders. The model principally includes both input and output indicators, detailed in Table 1.

Table 1. Input to output variables of mining enterprises

Variable type	Variable name	Calculation method
Input indicator		
Customer	Accounts receivable turnover rate (times)	Customer main business income/average accounts receivable
Supplier	Turnover rate of suppliers’ accounts payable (times)	Main business cost/average accounts payable
Creditor	Asset liability ratio	Total liabilities/assets
Shareholder	Basic earnings per share (CNY)	Net profit/average number of ordinary shares issued
Employees	Employee welfare rate	Cash paid to and for employees/cash outflow from operating activities
Government	Book income tax rate	Total income tax/profit
Output indicator		
Economic performance	Return on total assets	(Total profit+interest expense)/total average assets

Table 2. Statistical description of data

	Average value	Standard deviation
Return on total assets	0.085	0.056
Turnover rate of accounts receivable (times)	99.44	240.71
Accounts payable turnover rate (times)	19.514	23.565
Asset liability ratio	0.529	0.123
Basic earnings per share (yuan)	0.919	0.786
Employee welfare rate	0.072	0.046
Total income tax/profit	0.422	1.305

3. BCC (VRS) Model

3.1 Data Source and Descriptive Statistics

As per the 2022 Global Mining Report released by PricewaterhouseCoopers, nine Chinese enterprises secured positions among the top 40 listed mining companies globally in 2022. Notably, Shenhua claimed the fifth spot, followed by Zijin Mining, Tianqi Lithium, Shaanxi Coal, Luoyang Molybdenum, Yankuang Energy, Shandong Gold, China Coal Energy, and Jiangxi Copper. This study focuses on these nine representative listed mining enterprises, utilizing data from 2016 to 2021, sourced from Wind information. Table 2 shows the detailed information.

3.2 Model Setting

DEA serves as a tool for assessing the efficiency of resource allocation by constructing an input-output decision-making unit. This approach enables the evaluation of the economic performance of mining enterprises. This paper aims to establish a DEA model that initially considers the impact of variations in enterprise size on economic outcomes. The BCC (variable scale return [VRS]) model within DEA is employed to gauge the static economic efficiency of nine mining enterprises, specifically their technical efficiency. This metric reflects the utilization efficiency of mining enterprises and can be deconstructed into pure technology and scale efficiency. Pure technology assesses the application of existing technology, while scale efficiency evaluates the optimality of the input-output process. We have selected nine listed mining enterprises, each with one output variable and six input variables, resulting in a total of seven decision-making units. Each unit possesses an input vector, an output vector, and a possible production set, denoted as:

$$T = \left\{ (x,y) | \sum_{j=1}^{7} \lambda_j x_j \le x, \sum_{j=1}^{7} \lambda_j y_j \ge y, \sum_{j=1}^{7} \lambda_j = 1, \lambda_j \ge 0, j = 1,2...7 \right\}, \tag{1}$$

The DEA (VRS) model is expressed as:

$$\begin{aligned} & min[\theta - \varepsilon(\sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} S_i^*)] \\ & s.t. \sum_{j=1}^{7} X_{ij}\, \lambda_j + S_i^- = \theta_{ij\theta}, i \in (1,2 \dots m) \\ & \sum_{i=1}^{7} y_{rj}\, \lambda_j - S_r^+ = y_{rj\theta}, i \in (1,2 \dots s) \\ & \sum_{i=1}^{7} \lambda_j = 1, i \in (1,2...7);\ \theta, \lambda_j, S_i^-, S_r^+ \ge 0. \end{aligned} \tag{2}$$

3.3 Empirical Results and Analysis

Through an analysis of the BCC (VRS) model using DEAP2.1 software, we obtained the annual efficiency values of the nine listed mining enterprises from 2016 to 2021 are obtained. The specific efficiency values are summarized in Table 3.

As evident from Table 3, the annual average efficiency in bolds shows significant fluctuations in the overall efficiency of economic performance input-output among the nine listed mining companies. Both overall technical efficiency and scale efficiency exhibited a declining trend, with technical efficiency decreasing from 92.1% in 2016 to 78.9%, scale efficiency dropping from 92.4% in 2016 to 79.8%, and pure technical efficiency decreasing from 99.4% to 98.2%. These findings suggest that mining enterprises are experiencing a state of economic performance recession. To address this, enterprises must enhance their sense of responsibility, foster better relationships with stakeholders, and improve overall economic efficiency.

Table 3. Overall DEA efficiency of mining enterprises

Year	Overall mean of technical efficiency		
	crste	**vrste**	**scale**
2016	0.921	0.994	0.924
2017	0.871	0.999	0.871
2018	0.955	1.000	0.955
2019	**0.864**	**0.997**	**0.867**
2020	**0.779**	**0.987**	**0.783**
2021	**0.789**	**0.982**	**0.798**

The bold font indicates the significant fluctuations in the overall efficiency.
crste=constant returns-to-scale technical efficiency, vrste=variable returns-to-scale technical efficiency, scale=scale efficiency (ratio of crste and vrste).

Table 3 reveals that the scale efficiency of mining enterprises is lower than pure technical efficiency, indicating that the low scale efficiency of listed mining companies is a key factor contributing to low economic efficiency, thereby constraining enterprise development. Overcapacity in China's traditional mineral products, largely composed of primary products, hampers the reflection of scale effects. Mineral resource depletion, reduced industrial development space, and strategic mineral product dependence on imports further complicate matters. Recent challenges such as epidemics, political instability, nationalization, and global trade conflicts are unfavorable for large-scale mining development. Consequently, enterprises need to carefully determine an appropriate scale and strengthen the relationships with stakeholders.

Turning to Table 4, the DEA efficiency values for the nine listed mining enterprises from 2016–2021 are generally higher, except for Yankuang Energy and Shandong Gold. This indicates that most mining enterprises prioritize the needs of all stakeholders, maintain robust relationships with the company, and thereby contribute to the enhancement of enterprise economic performance. The common challenge faced by Yankuang Energy and Shandong Gold lies in poor relationships with employees and the negative interest rates. Additionally, considering the general principle of the DEA model where an efficiency value of 1 is considered effective and less than 1 is deemed inefficient or invalid, it is apparent from the table that Shaanxi Coal Industry and Zijin Mining have demonstrated the best input-output efficiency in the recent six years, indicating DEA effectiveness. Conversely, Yankuang Energy and Shandong Gold are almost invalid, underscoring the need to strengthen the construction of corporate social responsibility. The effectiveness of other enterprises' economic benefits is unstable, mainly because mining enterprises are vulnerable to the impact of the environment and upstream enterprises.

Table 4. DEA efficiency of listed mining enterprises from 2016 to 2021

Year	China Shenhua	Yankuang Energy	China Coal Energy	Shanxi Coal Industry	Jiangxi Copper Industry	Zijin Mining Industry	Shandong Gold	Luoyang Molybdenum Industry	Tianqi Lithium Industry
2016	1.000	0.394	0.899	1.000	1.000	1.000	1.000	1.000	1.000
2017	0.649	0.596	1.000	1.000	1.000	1.000	0.591	1.000	1.000
2018	1.000	0.936	1.000	1.000	1.000	1.000	0.657	1.000	1.000
2019	1.000	0.780	0.672	1.000	0.696	1.000	0.857	0.771	1.000
2020	1.000	0.310	1.000	1.000	0.750	1.000	0.729	0.852	0.368
2021	0.762	0.409	0.823	1.000	1.000	1.000	0.109	1.000	1.000

4. Malmquist Index Method

4.1 Model Setting

The Malmquist index method serves as a tool for analyzing the total factors of mining enterprises using panel data, measuring technological advancements from period t with a priority assumption to ascertain the technological state in period $t+1$, as denoted in Eq. (3):

$$M^t = D_i^t(x^t, y^t)/D_i^t(x^{t+1}, y^{t+1}) \tag{3}$$

Utilizing the geometric mean value of the static model index, the total factor productivity (TFP) of efficiency changes from t to $t+1$ can be calculated, as denoted in Eq. (4).

$$\text{TFP}(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D_i^{t+1}(x^{t+1},y^{t+1})}{D_i^t(x^t,y^t)}\left[\frac{D_i^t(x^t,y^t)}{D_i^t(x^t,y^t} * \frac{D_i^t(x^{t+1},y^{t+1})}{D_i^{t+1}(x^{t+1},y^{t+1}}\right]^{\frac{1}{2}}. \tag{4}$$

When TFP > 1, it signifies an upswing in the efficiency level of mining enterprises. TFP < 1 indicates a recession, and TFP = 1 denotes constant efficiency.

4.2 Empirical Results and Analysis

Table 5 presents the total factor productivity measurement results for the nine listed mining enterprises from 2016 to 2021. After incorporating social relations into the analysis, the overall TFP is 0.976, indicating a recessionary period in the overall economic performance of mining enterprises. This is primarily attributed to mining enterprises being positioned upstream in the industrial chain, rendering them susceptible to downstream enterprises and external environmental influences, which has been notably unstable in recent years. Notably, the efficiency measurements for the periods 2016–2017, 2018–2019, and 2020–2021 surpass 1, while other periods exhibit values below 1. This suggests that the trend of technical progress and the measured value of total factor productivity align more closely than that of pure technical efficiency. Consequently, technical progress emerges as the predominant factor influencing economic efficiency. Additionally, the change values of the technical efficiency index and the scale efficiency index exhibit remarkable similarity, indicating that scale efficiency is the primary factor influencing technical efficiency.

Table 5. Overall total factor productivity of mining enterprises

Year	EC	TC	PTC	SEC	TFP
2016–2017	0.953	1.238	1.005	0.947	1.179
2017–2018	1.116	0.770	1.001	1.115	0.859
2018–2019	0.901	1.170	0.997	0.904	1.054
2019–2020	0.845	0.919	0.989	0.854	0.776
2020–2021	0.931	1.148	0.994	0.937	1.069
Mean	0.945	1.033	0.997	0.948	0.976

EC=efficient change, TC=technical change, PTC=pure technical change, SEC=scale efficiency change.

Table 6 presents a comprehensive overview of the total factor productivity for the nine mining enterprises. The decomposition results reveal several key insights. Firstly, entities such as China Shenhua, Yankuang Energy, Shaanxi Coal, Jiangxi Copper, Zijin Mining and Luoyang Molybdenum exhibit total factor productivity values exceeding 1. In contrast, China Coal Energy, Shandong Gold and Tianqi Lithium have estimated values below 1. This suggests that, after accounting for corporate social responsibility, the economic efficiency of China's mining enterprises is generally robust, with only three experiencing a decline.

Secondly, an observed trend alignment between the measured values of technological progress and the majority of mining enterprises' total factor productivity indicates that changes in total factor production are predominantly influenced by technological progress. Notably, the factors influencing the total factor production of China Coal Energy are primarily attributed to variations in technical efficiency, with the latter being significantly influenced by changes in pure technical efficiency.

Thirdly, the principal factor constraining the advancement of technical efficiency across mining enterprises is identified as scale efficiency.

Table 6. Fully required productivity of listed mining enterprises from 2016 to 2021

Company	EC	TC	PTC	SEC	TFP
China Shenhua	0.947	1.113	1.000	0.947	1.054
Yankuang Energy	1.008	1.079	0.977	1.031	1.087
China Coal Energy	0.983	0.967	1.000	0.983	0.950
Shanxi Coal Industry	1.000	1.057	1.000	1.000	1.057
Jiangxi Copper	1.000	1.078	1.000	1.000	1.078
Zijin Mining	1.000	1.053	1.000	1.000	1.053
Shandong Gold	0.642	1.067	1.000	0.642	0.685
Luoyang Molybdenum Industry	1.000	1.027	1.000	1.000	1.027
Tianqi Lithium	1.000	0.877	1.000	1.000	0.877
Average value	0.945	1.033	0.997	0.948	0.976

5. Conclusion

The study, utilizing data envelopment analysis and drawing upon six years of data from 2016 to 2021, comprehensively examines the economic performance of nine listed mining enterprises based on corporate relations. The analytical findings yield the following key insights: from a static perspective, the overall economic performance of mining enterprises reflects a state of recession, attributed to the underperformance of Yankuang Energy and Shandong Gold; Breakdown data suggests that scale efficiency predominantly hinders the growth of economic efficiency. On a dynamic level, technological progress emerges as a principal influencer of economic performance for mining enterprises, with scale efficiency within technical efficiency standing out as a primary hindrance to overall development.

The root causes behind the fluctuating economic performance of mining enterprises remain insufficiently explored, paving the way for subsequent in-depth research endeavors.

Acknowledgement

This paper was funded by the Innovation and Strengthening School Quality Project in 2022 from Guangdong University of Science and Technology Project (No. GKY-2022CQTD-6, Research team on collaborative governance of urban agglomeration innovation network in Guangdong Hong Kong Aoda Bay Area).

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