Review on the evaluation of green development of mining industry

Jie Huang 1,2, Liang Yinping 3, Peng Yue 3,*
1 School of Economics and Management, China University of Geosciences, Beijing, China
2 China Academy of Natural Resources Economics, Beijing, China
3 Cores and Samples Center of Land & Resources, Sanhe, Hebei, China

*Corresponding author e-mail: yuepeng@mail.cgs.gov.cn

Abstract: With the continuous acceleration of green development of mining industry, a series of research results around the evaluation of green development of mining industry have been obtained. This paper reviews the literature about green mining concept, sustainable development and circular development of mining industry, scientific mining evaluation, green performance evaluation in foreign countries and green mine evaluation, green mining evaluation and other related green development evaluation in China. Based on the summaries, the challenges and prospects of green development evaluation of mining industry are proposed and they can provide favorable foundation and guidance for further innovation of mining green development evaluation systems and methods.

1. Background
With the green development of China's mining industry, the green mines and green mining development demonstration areas are increasing. The analysis and conclusion of reasonable evaluation of the green development of the national mining industry, comparison of the development gap, analysis on the influencing factors is significant to advance the green development of mining industry and construction of green mines. In these years, more and more scholars have obtained a series of research results around the evaluation of green development of mining industry. This paper reviews the relevant literature to provide favorable foundation and guidance for the scientific evaluation of green development of mining industry in China.

2. Research on green development evaluation of foreign mining industry
Currently, the research on green development evaluation of foreign mining industry mainly focuses on macro-economy, ecological environment, resources and energy. A few countries have put forward the conception of “Green Mining” and there are not many studies about green development evaluation of mining industry. Canada and Finland have put forward the conception of “Green Mining”. In Canada, the conception of "Green Mining" was advanced, furthermore the "Green Mining Initiative" was issued. The "Green Mining" in Canada is to reduce the waste generated during mining as much as possible, turn it into environmental resource leaving clean water and restore landscape and healthy ecosystem through creative methods. The “Green Mining Initiative” includes five innovative themes: clean water, best
practices in mining environment management, energy efficiency in mining and beneficiation, mineral development in the north of the country and innovation of mineral concentration. In 2011, Finland introduced the special study on “Green Mining Plan (2011-2016)”, with the purpose of 5 breakthroughs by new technologies and methods: increasing efficiency of materials and energy, ensuring the availability of future demand for mineral resources, minimizing the negative impact on the environment and society, improving the performance of work and organization management and ensuring the sustainable use of land after closing mine. The government aims to make Finland a responsible pioneer of green mining in the world.

2.1. Sustainable and circular development of mining industry
In sustainable and circular development of mining industry, the responsibility of government and enterprise, utilization of waste and post mining strategy are emphasized. In the research on mining and sustainable development, Lambert suggested that the government have responsibility for ensuring the comprehensive environmental and social impact assessment process before the approval of mining projects and an effective monitoring and reporting system preserved to ensure the approved environmental and social management plan to be performed. Enterprises should under take major responsibilities in sustainable and circular development of mining industry, specially in reducing waste and interference during mining, disposal of waste and site remediation. They should still need to partner with government bodies in research and development to help optimize economic returns and minimize the impact on the environment[1]. In “from Mining to Post-Mining: the Sustainable Development Strategy of the German Hard Coal Mining Industry”, Kretschmann et al proposed that the coal industry in Germany is facing long-term restructuring pressure, and needs a new coal mining industry strategy, from active hard coal production to post coal-mining, to prepare for the post-mining era, such as the photovoltaic power stations in mining areas, the power plants generated by mine water or waste heat, wind wheels on dustbins, garbage yards or pumped storage under existing mine structure and geothermal energy, etc[2]. Long and Zhang analyzed the circular economy of mining area based on the entropy theory in Negative Entropy Mechanism of the Circular Economy Development Countermeasures in Mining Area. A large number of wastes produced in the process of coal mining lead to the increase of entropy in the mining area. However, the wastes are useful resources for other industries, which can be introduced to consume them and they generate useful negative entropy flow to realize the effective recycling of resources[3].

2.2. Scientific mining evaluation and green performance evaluation
Li and Nie have carried out some exploring researches in the scientific mining evaluation and green performance evaluation of mineral resources, established key indicators to evaluate the scientific mining level of coal resources in China's coal resources scientific mining evaluation system. The evaluation system consists of 5 dimensions: informatization, productivity, safe mining, full cost and green mining, 18 standards and 56 evaluation factors. The evaluation model of scientific mining was established based on the evaluation method of comprehensive index[4]. In the performance analysis and evaluation index system of green mineral (phosphate) in China, Shang et al constructed the major index system and 16 minor indexes in social benefits, environmental qualification, enterprise management, cleaner production, research and development, mining efficiency, etc., and established the evaluation model by Delphi Method, Analytic Hierarchy Process and Comprehensive Fuzzy Judgment Method[5].

3. Research on green development evaluation of mining industry in China
The research on green development evaluation of mining industry in China mainly focuses on the evaluation of green mines and the evaluation of green mining economy based on regional scale. Other related researches include green industry evaluation and China green development index. Because of the different research content, the meaning and index measure of green development estimates are also very different.
3.1. Research progress of green mine evaluation

With regard to theories and methods of green mine evaluation, the indexes have been designed and studied from different perspectives, such as resource utilization, ecological protection, scientific and technological innovation, social security, competitiveness and management ability of mines. Xue analyzed the internal and external environment of green mine construction in China and its political, economic and social and technical advantages and disadvantages with SWOT and PEST-SWS models respectively, and concluded that the emphasis of green mine construction is the integration of land use and mineral exploitation[6]. Zhang et al divided the green mine construction into three levels: the general level, the system level and the evaluation index level, which included 28 evaluation indexes, and established the evaluation system of green mine construction by Analytic Hierarchy Process. Wang suggested to construct a comprehensive evaluation index system of green mines from 23 third-class indicators of 4 second-class indicators involving degrees of harmonious development, resource utilization, ecological protection and scientific and technological support. The index system was verified by practical cases[8]. Xu et al have constructed a green mine evaluation index system including 7 primary and 25 secondary indexes according to 9 basic conditions in Basic Conditions of National Green Mine. Taking the actual mine as an example, the Entropy Method and Minimum Cross-entropy Model were established by expert scoring method, and the subjective and objective weights were integrated, and the comprehensive evaluation results were finally obtained[9]. Using the menu type multi-index index system of the United Nations Commission on Sustainable Development, Yang et al constructed the green mine evaluation index system including 3 primary indicators and 9 secondary indicators, which respectively covered the comprehensive indicators of social security, comprehensive utilization of resources and comprehensive indicators of environmental protection. In the research, the linear weighted average method was used to calculate the score[10]. Based on the life cycle evaluation theory, Yan et al identified the pollution sources in the mine construction, built a green mine evaluation standard system which is correspond with Chinese national conditions, and explored the evaluation method of green mines referring to the evaluation methods of green buildings with Analytic Hierarchy Process and Comprehensive Fuzzy Judgment Method[11].

3.2. Research progress of green mining evaluation

Research of green mining mainly on the regional-scale quantitatively constructs the comprehensive evaluation index system including social, economic, resource, environmental and other factors. Underpinned by systematical investigations on the development and utilization of mineral resources in Altay of Xinjiang, Sun analyzed various influence factors and characteristics of green mining development, designed a set of evaluation index system of regional green mining economy and applied it in Altay[12]. With the application of the contribution index and econometric model, Mimadunzhu made a systematic estimation on the contribution of Tibet's mining industry. The ecologically vulnerable areas in Tibet were preliminarily evaluated and divided, and development mode of green mining in these areas is studied and determined[13]. Gu et al established the evaluation index system of mining vulnerability, proposed harmony degree of ecosystem and set the classification standard of its vulnerability and harmony[14]. Pan proposed the evaluation method of “Energy Value” and “Green GDP” from the perspective of ecological economics, and supposed that the evaluation of green mining industry should pay attention to the economic and environmental effects of the involving upper and lower streams industries of mineral resources from the perspective of industrial chain development.

3.3. Other interrelate researches

Beijing Normal University, Southwest University of Finance and Economics and the State Bureau of Statistics constructed a set of green development evaluation index system, which consists of one target layer, three evaluation levels and 55 specific indicators. According to the index system, the green development index of each province or city in China was evaluated and analyzed with Subjective Weighting Method and Weighted Sum Method. In the regard of the evaluation of green industry development, Su et al defined the connotation of green development of industry from green production,
green products and green industry for the first time. Around the theme of green production, the “Industrial Green Development Performance Index” based on comprehensive index method was constructed[17]. Yu et al built the cycle model of the coal industry in China adopting the synthetic index model and the cross correlation coefficient analysis method[18]. Regarding 30 provinces and cities in China as the research objects, Chu’s EntropyWeight-TOPSIS model of the industrial green development index was constructed. Based on it, the industrial green development index of China in 2003-2012 was estimated by MATLAB and the regional differences in 30 provinces and cities were analyzed in depth by scoring method[19]. The evaluation index system of Liu et al for green development of regional industry is according to following four aspects: resource utilization efficiency, low carbon emission, resource recycling and reuse and green development potential[20].

4. Summaries and prospects

With the continuous researching at home and abroad, the theory and method of green development evaluation are constantly improving, which has important implications for the measurement of green development level, but there are also some problems, which are common challenges in the future research.

First, the evaluation index system of green development of mining industry at home and abroad is mainly used to reflect the level of green development of mining industry, but the emphasis of the index system is different due to the difference of regional economic development. Foreign studies mainly focus on resources and environment, social welfare and human welfare. Research in China has shifted from economic development to the relationship between environment and economic growth. Due to the difference of evaluation index and analysis method, the evaluation results of the same target are often different.

Secondly, the evaluation index system of green development of mining industry at home and abroad is greatly influenced by subjective and cultural factors. The evaluation index of green development needs the guidance of scientific theory to avoid the constraints of subjective and cultural factors. At the same time, there are many other problems, such as the complex index framework, the difficulty of index quantification, the unreasonable weight distribution and so on.

Third, the current research mainly focuses on the mining economy and the construction of green mine in some certain mining areas, key regions and typical provinces. The evaluation at the national level is not so competent, so the evaluation of green development in the mining industry is still in exploration.

In conclusion, the evaluation of mining green development should emphasize the combination of green and development, give enough consideration to the characteristics of mineral resources development and utilization, and synthesize economy, resources, environment, government and society. Combined the main contents, dominant feature, functions and data collection situation, the paper puts forward the compilation ideas, principles and construction methods of the evaluation index system of mining green development with different scales. Considering the different influences and functions of various factors at the same level, the weight of each factor should be determined through the combination of subjective and objective methods, and the relevant methods of standardization should be referred to ensure the clear meaning of standardized mathematical theory and the achievement of horizontal and vertical comparability of indicators. The determination of evaluation model should refer to the main methods of index research, consider the content and purpose of mining green development and weigh up the advantages and disadvantages of various methods.

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