ISSN 2616-5902 Vol. 5, Issue 23: 20-32, DOI: 10.25236/AJBM.2023.052304

Research on the Impact of Environmental Regulation and Supply-side Structural Reform on the Innovation of the Mining Industry

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Abstract: *Proposed the goals of "peak carbon dioxide emissions" by 2030 and "carbon neutrality" by 2060. The central government and all levels of government have adopted environmental regulation in the field of environmental management to promote technological innovation in enterprises in order to improve their soft power. This has had a great impact on the social environment. Since the reform and opening up, coal has occupied a major position in China's energy consumption structure. In 2022, total coal consumption accounted for 56.2% of China's total energy consumption. Even though new energy technologies have gained significant breakthroughs in recent years, and the production of other energy sources such as hydropower, nuclear power, wind power and so on has increased dramatically, the position of coal as the ballast of China's energy supply and consumption remains unchanged. In this paper, supply-side structural reform of the mining industry for the period 2018-2022 environmental regulation government related policies as well as legal documents, and industry and company data such as the mining industry as well as listed coal companies are examined. Meanwhile, entropy method and panel model are applied to explore the impact of environmental regulation and supply-side structural reform on innovation in the mining industry during 2018-2022.*

Keywords: *Environmental regulation, Supply-side structural reform, Mining industry, Enterprise innovation*

1. Introduction

In 2022, China's total energy consumption was 541,000 tonnes of standard coal, and the total consumption of coal accounted for 56.2% of China's energy consumption structure. In the past 20 years, although the proportion of coal consumption in the energy consumption structure has experienced a long-term downward trend, China's energy consumption structure has always been dominated by coal. Due to China's "coal-rich and oil-poor less gas" resource endowment, its mining industry in all fossil energy as China's energy self-sufficiency ballast position has not changed, and in China's economic growth and energy security has made great contributions. However, it is undeniable that the rough management of the mining industry and pollution emissions as well as other phenomena have brought great impact on China's environmental protection. The environmental regulation will force the mining industry to carry out transformation and upgrading, and the mining industry will definitely face the pain brought by transformation and upgrading. But after the industry reform is completed, the technological innovation level of coal enterprises will also make a qualitative leap. For example, Shaanxi Coal, a listed company, is working with Huawei and other companies to build a "5G+Industrial Internet" smart mine. Through the application of digital technology, the number of people working underground in the Hongliulin coal mine of Shaanxi Coal has dropped by 18%, and the rate of intelligent coal mining in the working face has reached 97.7%. In Shaanxi Coal's Xiaobaodang Coal Mine, the integration of intelligent mining processes, equipment, management and 5G as well as other technologies has significantly improved the level of safety operations and coal production efficiency. The number of people supporting the underground working face has been reduced by 42%, and corporate efficiency has been improved. In 2022, Shaanxi Coal's net profit attributable to shareholders of the parent company after deducting non-operating gains and losses was about RMB 29.411 billion. It exceeds the company's best-ever performance, reduces its environmental impact, and contributes more to social development. Back to the paper itself, although the literature on environmental regulation for the industry investment efficiency and industry development has been discussed, but the lack of consistency of viewpoints, it needs more correlation research. This paper uses the proportion of R&D investment in operating income, the proportion of R&D personnel in employees, and the number of corporate patents as the enterprise innovation index. At the same time, it takes the implementation of Environmental Protection Tax Law of the People 's Republic of China in 2018 as the starting point to verify the role of environmental regulation in enterprise innovation and enterprise performance.

2. Literature Review

2.1 The role of environmental regulation in business performance

As public awareness of environmental protection has increased in recent years and the government has formulated more environmental regulation policies and introduced relevant measures, the relevant enterprises have increased their investment in environmental protection and research and development of production as well as other aspects of the enterprise, to promote the renewal of the product. This behaviour increases the cost investment of enterprises, which will inevitably have an impact on the performance of enterprises. Domestic scholars have studied the direction and extent of the impact of this behaviour on enterprises, mainly including traditional hypothesis, uncertainty hypothesis and porter hypothesis three theories. According to the existing literature, the relationship between environmental regulation and enterprise performance is mainly facilitating and inhibiting.

2.1.1 "Porter hypothesis"

In 1979, economist Richard Porter proposed the "porter hypothesis". The hypothesis suggests that although environmental regulation will lead to higher costs for firms over time, appropriate environmental regulation policies can, to a certain extent, promote more innovative activities by firms. The outputs of these innovative activities will increase the production efficiency and productivity of the firms, which will bring more benefits to the firms, thus weakening the increase in production costs brought about by environmental regulation and enhancing the competitiveness of the firms in the relevant markets, improving the quality of the products, thus increasing the revenues and profits of the firms. At the same time, it has the potential to increase industrial productivity. Some scholars in China believe that environmental regulation has a facilitating effect on enterprise performance. China's scholars Ye Hongyu, Wang Shengjie (2017) used the panel data of listed companies in the domestic heavy pollution industry from 2011 to 2014, and the results of the study proved the existence of "porter hypothesis" in China's heavy pollution industry.[1] In addition, scholars Ren Shenggang, Zheng Jingjing and Liu Donghua (2019) used double difference method, triple difference method and instrumental variable method to process the data at the provincial and prefectural level, which effectively proves that the mechanism of sewage trading improves the enterprise's total factor productivity[2] .

2.1.2 Traditional hypothesis

The traditional hypothesis was firstly put forward in foreign countries, represented by Jaffe (1995), which argues that the environmental regulation policy formulated by the government will increase the enterprise's investment in environmental protection and governance. It will divert the enterprise's investment and negatively affect the enterprise's performance[3]. Some domestic scholars believe that environmental regulation has a positive effect on enterprise performance. By using the data and econometric methods of China's standard industry from 1996 to 2004, our scholar Zhao Hong (2007) proved that the policy of environmental regulation not only did not increase the barriers for enterprises to enter the new industry, but also attracted more enterprises to enter the industry, which resulted in the aggravation of the industry's competition and the decline of the industry's profit margins.[4]

2.1.3 Uncertainty hypothesis

The hypothesis argues that different enterprises are at different stages of development and face different environmental characteristics. The above two points are heterogeneous, so the impact of environmental regulation on enterprise performance cannot be determined, resulting in no stable relationship between environmental regulation and enterprise performance. China's scholars Wang Delai (2023) used a three-stage DEA model to test the technical efficiency of energy enterprises, and the conclusion proved that there is a large difference in the impact of heterogeneous environmental regulation on the performance of energy enterprises[5].

2.1.4 Mediation effect theory

The mediation effect theory refers to the fact that there is no direct relationship or effect between two

ISSN 2616-5902 Vol. 5, Issue 23: 20-32, DOI: 10.25236/AJBM.2023.052304

variables (variable X and variable Y), which are mainly affected through one or more other variables. In this case, the variable Z acts as a mediating variable. The transmission mechanism of a variable is through the variable X affects the variable Z. The variable Z affects the variable Y, i.e. the variable X has an indirect effect on the variable Y through the variable Z as a mediator.

2.1.5 Conduction pathway of environmental regulation

Our scholars Cheng Xiling et al. put forward the transmission mechanism of environmental regulation for the development of mining industry[6] , as shown in the following figure 1.

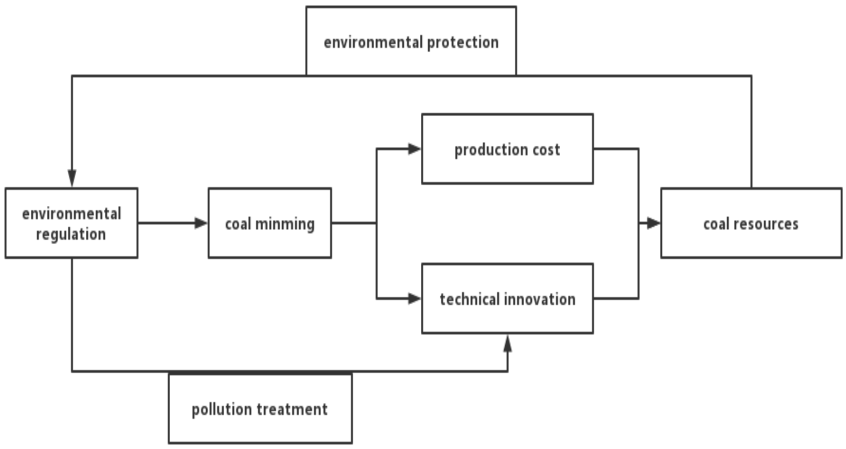

Figure 1: Transmission mechanism of environmental regulation for mining industry

First of all, in the past, due to the unlimited exploitation of coal resources caused more environmental pressure, the use of environmental protection introduced environmental regulation, environmental regulation for coal mining puts forward more requirements, and for enterprise production costs and technological innovation puts forward more requirements, so as to more efficient use of coal resources. Reviewing the existing studies, most of the literature uses the relevant panel data from 2011-2020 as the sample. However, for the mining industry, the environmental regulation should adopt the data of 2018-2022 as more appropriate for this industry. The main reason is that the environmental regulation for this industry is mainly command-type environmental regulation, which means that the government sets pollution emission standards by enacting laws and administrative regulations. Through laws and regulations, the government restricts environmentally hazardous behaviours and imposes legal penalties and sanctions on offenders. In addition, state-owned enterprises (SOEs) account for the majority of listed coal companies in China. In the sample screening, a total of 17 samples passed the screening criteria, and only 2 companies are private enterprises, such as China Shenhua, the leading company in China's mining industry. As of the end of 2020, the State Council's State-owned Assets Supervision and Administration Commission owns 69.45% of the shares of China Shenhua, and the government has strong control over the industry. In addition, the introduction of Environmental Protection Tax Law of the People 's Republic of China is a relevant embodiment of environmental regulation in this industry, so the relevant panel data from 2018-2022 should be used as the data source. This thesis builds on the above literature base for further research.

3. Overview of the Development of the Mining Industry

3.1 The mining industry dominates the country's energy consumption

It can be found in the table 1 and table 2 that China's total energy consumption from 2003 to 2022 has been increasing with China's economic development. The proportion of fossil energy consumption represented by coal and oil, and natural gas decreases from 92.6% to 82.5%. In the long term, the share of coal and oil consumption continues to decline, and natural gas consumption and primary electricity and other energy sources increase year by year. However, the absolute amount of coal consumption will break through a new high in 2022, and it will still account for more than 50% of China's energy consumption.

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Table 1: China's Energy Consumption and Total Coal Consumption

Time	Total energy consumption (10,000 tonnes of standard coal)	Total coal consumption (10,000 tonnes of standard coal)
2003	197083	138352.266
2004	230281	161657.262
2005	261369	189231.156
2006	286467	207402.108
2007	311442	225795.45
2008	320611	229236.865
2009	336126	240666.216
2010	360648	249568.416
2011	387043	271704.186
2012	402138	275464.53
2013	416913	280999.362
2014	428334	281843.772
2015	434113	276964.094
2016	441492	274608.024
2017	455827	276231.162
2018	471925	278435.75
2019	487488	281280.576
2020	498314	283540.666
2021	525896	293975.864
2022	541000	304042

Source: National Statistical Office

Table 2: China's Energy Consumption Structure

Time	Share of coal in total energy consumption	Share of oil in total energy consumption	Share of natural gas in total energy consumption	Primary electricity and other energy sources as a share of total energy sources
2003	70.20%	20.10%	2.30%	7.40%
2004	70.20%	19.90%	2.30%	7.60%
2005	72.40%	17.80%	2.40%	7.40%
2006	72.40%	17.50%	2.70%	7.40%
2007	72.50%	17%	3%	7.50%
2008	71.50%	16.70%	3.40%	8.40%
2009	71.60%	16.40%	3.50%	8.50%
2010	69.20%	17.40%	4%	9.40%
2011	70.20%	16.80%	4.60%	8.40%
2012	68.50%	17%	4.80%	9.70%
2013	67.40%	17.10%	5.30%	10.20%
2014	65.80%	17.30%	5.60%	11.30%
2015	63.80%	18.40%	5.80%	12%
2016	62.20%	18.70%	6.10%	13%
2017	60.60%	18.90%	6.90%	13.60%
2018	59%	18.90%	7.60%	14.50%
2019	57.70%	19%	8%	15.30%
2020	56.90%	18.80%	8.40%	15.90%
2021	55.90%	18.60%	8.80%	16.70%
2022	56.20%	17.90%	8.40%	17.50%

Source: National Statistical Office

According to data from the National Energy Administration and the General Administration of Customs, China's coal production was 4.45 billion tonnes and coal imports were 293 million tonnes in 2022. From that data, it can be found that China's coal consumption is mainly dominated by domestic coal. Compared with other fossil energy sources, China's coal plays a huge role in our energy supply and security.

3.2 The development stage of China's mining industry

By using the amount which is shown in the following figure 2 of investment in fixed assets of coal mining and washing industry as an indicator, the development of China's mining industry from 2003 to the present is divided into four periods.

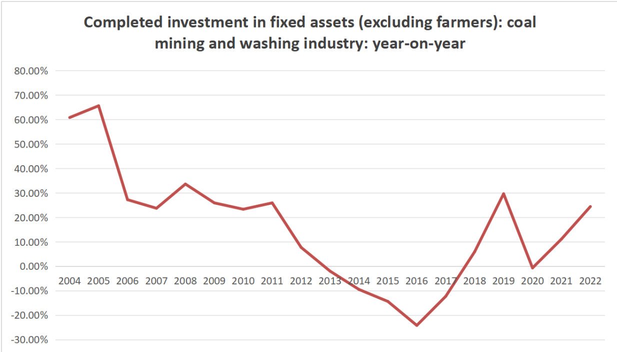


Figure 2: Fixed Asset Investment in Coal Mining and Washing Industry

In the first stage, (2003-2011) China's economy entered into a stage of rapid development, the state abolished the national guide price of electric coal (used in thermal power generation), the coal price gradually became market-oriented, and the mining industry entered into a period of rapid development as a result. In 2002, along with China's accession to the World Trade Organisation (WTO), and the GDP achieved a high growth rate. In 2002-2008, the compound annual growth rate of GDP was more than 8%. The rapid economic development boosted the total demand for coal, the elasticity coefficient of energy consumption was greater than or equal to 0.3, and the growth of energy consumption showed a positive correlation with the growth of GDP. The demand for energy increased, and the supply of coal market exceeded the demand. The price of coal continued to be elevated during this period of time. Coal enterprises, driven by high profits, actively expanded investment and production to meet market demand. In 2008, although the export economy was hit by the global financial crisis, but the country introduced the "four trillion plan" related policies to stimulate consumption and infrastructure construction, the national economic growth rate. Although there is a certain rate of decline, the mining industry in 2008-2011 still maintained more than 20% growth rate of fixed asset investment. Until 2012, the mining industry investment growth rate into a downward channel.

In the second stage, (2012-2016) in 2012, the global economic growth rate slowed down, commodities by the demand side of the demand reduction impact of prices continued to fall. The mining industry in 2008 "four trillion plan" demand stimulus, capacity expansion than downstream demand growth rate. The mining industry is oversupplied, and the pivot of coal prices has fallen sharply. At the same time, the capacity structure of coal enterprises gradually highlighted the problem. Overcapacity is a serious problem, and the industry's capacity utilisation rate is declining year by year. The mining industry has entered a long capacity clearance stage. The state put forward supply-side structural reform in 2016, using policy instruments to accelerate the elimination of excess capacity and backward capacity. In the same year, mining industry investment growth bottomed out. In 2017, mining industry fixed investment bottomed out.

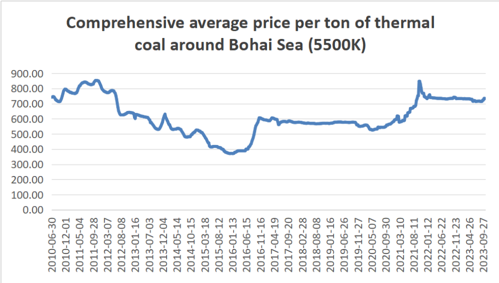
In the third stage (2016-2020), after the "Thirteenth Five-Year Plan" put forward supply-side structural reform, under the state's macro-control, the coal enterprises to increase production capacity. In February 2016, the mining industry supply-side reform policy represented by the State Council's important policy opinion [2016] No. 7 began. A large amount of backward production capacity was eliminated, and advanced production capacity was released to guarantee supply. The structure of production capacity is constantly optimised, superimposed on the industry's capital expenditure has continued to decline for many years, and it has led to the basic clearing of production capacity. The demand side along with the development of emerging industries and urban residents living standards, social electricity consumption growth, the supply and demand structure has been improved to some extent, coal prices rebound and tend to stabilise.

In the fourth stage (2021-present), after the impact of the epidemic, which had a serious impact on the domestic macroeconomy, coal prices experienced a significant shock. After 2021, the economy recovered and energy demand gradually recovered. However, due to the "stockpile" period a large number of mine closure, new capacity investment is more obvious insufficient, which caused a shortage of domestic coal production capacity. At the same time, the Russian-Ukrainian conflict and the impact

ISSN 2616-5902 Vol. 5, Issue 23: 20-32, DOI: 10.25236/AJBM.2023.052304

of the epidemic, coal imports contracted sharply, which in the short term exacerbated the domestic coal supply gap, the coal price pivot upward rapidly.

And the price per ton of thermal coal between June of 2010 and September of 2023 could be seen in the figure 3.



Note: Bohai Power Coal Price Index is a relevant index reflecting the fluctuation of FOB closeout price and price level of coal used for coal-fired power generation in the northern ports, and the statistics include transaction data from six ports such as Huanghua Port, Qinhuangdao Port, etc. Since coal from China's major coal-producing areas of Shanxi Province, Shanxi Province, Inner Mongolia, etc. is mainly loaded from the above ports to the south. The index has a better representativeness.

Figure 3: Bohai Power Coal: Composite Average Price (5500K)

3.3 Laws and policies related to supply-side structural reform and environmental regulation in China's mining industry in 2015-2020

3.3.1 Related policies of supply-side structural reform

And the related policies of supply-side structural reform could be seen in the table 3.

Table 3: Supply-Side Policies

Time	Relevant documents	Summary of policy content
February 2016	The State Council issued the Opinions on the mining industry's dissolution of overcapacity and realisation of its breakaway development (The State Council issued [2016] No. 7)	The opinion states, "Starting from 2016, it will take 3-5 years to withdraw 500 million tonnes of backward coal production capacity, reduce supply restructuring capacity by 500 million tonnes, compress coal production capacity by a relatively large margin, and moderately reduce the number of operating coal mines."
April 2016	The Ministry of Human Resources, the State Administration of Coal Mine Safety, the National Energy Administration and the National Development and Reform Commission jointly issued the Circular on Further Regulating and Improving the Order of Coal Production and Management	The notice stipulates that, starting from 2016, all coal mines across the country will organise production in accordance with the 276 working days per year rule, and will directly multiply the existing production capacity by a coefficient of 0.84 (276 days divided by the original stipulated working days of 330 days) and take the integer as the new production capacity in compliance with the rule.

3.3.2 Law and policy of environmental regulation

And the environmental regulation laws and policies could be seen in the table 4.

Table 4: Environmental Regulation Laws and Policies

Time	Relevant documents	Summary of policy content
January 2015	Law of the People's Republic of China on Environmental Protection	It provides for the discharge of pollutants in excess of national or local standards to be subject to the payment of excess sewage charges in accordance with the provisions of the law.
January 2018	Environmental Protection Tax Law of the People 's Republic of China.	Enterprises, institutions and other producers and operators that discharge taxable pollutants into the environment are taxpayers of environmental protection tax and shall pay environmental protection tax in accordance with the provisions of this Law.

ISSN 2616-5902 Vol. 5, Issue 23: 20-32, DOI: 10.25236/AJBM.2023.052304

4. Empirical Studies

4.1 Selection of variables

4.1.1 Environmental regulation variables

As a form of regulation for enterprise production and operation, domestic scholars have different measurement methods for environmental regulation, and the following five methods are used to obtain specific measurable data:

1) Using the amount of enterprise environmental protection investment. For example, scholars Li Shu, Zhao Xiaole and Lou Changlong (2016) used the ratio of regional environmental governance investment to regional industrial output value divided by the ratio of regional GDP to regional industrial output value as an indicator of the environmental regulation variable.[7]

2) The number of environmental penalty cases of relevant enterprises. For example, scholars Wang Yun, Li Yanxi and Ma Zhuang (2020) used the data of environmental administrative penalties of enterprises as the environmental regulation variable.[8]

3) Using the ratio of investment in environmental pollution control to total industrial output value. For example, our scholars Yu Xiangyu, Li Yue and Chen Huiying (2019) used investment in environmental pollution control as an environmental regulation variable[9]. Tao Changqi, Li Cui and Wang Xiahuan (2018) used the amount of investment in pollutant treatment per unit of output over the national investment in pollutant treatment per unit of output as a measure of environmental regulation[10].

4) Pollution emission indicators. For example, our scholars Wang Jie and Liu Bin (2014) used wastewater discharge compliance rate sulfur dioxide removal rate soot removal rate dust removal rate and solid waste comprehensive utilisation rate related indicators to measure the level of environmental regulation[11].

5) Other indicators. For example, our scholars Zhang Cheng, Lu Yang, Guo Lu (2011) used the ratio of total investment in industrial pollution control to the main business cost and industrial added value of industrial enterprises above the scale in different regions as indicators of the intensity of environmental regulation.[12]

This paper focuses on listed companies in the mining industry to explore the impact of environmental regulation on enterprise innovation and enterprise performance. In order to avoid the difference in the size of listed companies, the intensity of environmental regulation, i.e., the amount of completed investment in pollution control per thousand yuan of industrial output value, is used as the environmental regulation variable. The calculation formula is as follows:

$$\text{Environmental regulation intensity} = (\text{completed investment in pollution control}/\text{gross industrial output value})*1000 \tag{1}$$

4.1.2 Enterprise innovation variables

For enterprise innovation variables, scholars at home and abroad mainly measure enterprise innovation from two aspects. The first is the input of enterprise R&D, which mainly includes such indicators as enterprise R&D input and the number of R&D personnel. The second is the output of enterprise research results, mainly including the number of enterprise patents and innovative product sales revenue and other indicators. For example, our scholar Zhang Yi (2021) used R&D expenditure, new product development expenditure and full-time equivalent of R&D personnel and total investment in environmental pollution control as input indicators[13]. In addition, the scholar Sun Haibo (2023) used the ratio of enterprise R&D investment to operating revenue as a measure of enterprise innovation variable[14]. Although this indicator can avoid the influence of enterprise size on R&D investment, a single indicator cannot objectively reflect enterprise innovation. Enterprise innovation needs to be observed from multiple perspectives. This paper uses the ratio of enterprise R&D investment to operating revenue, the ratio of the number of R&D personnel to employees, and the number of enterprise patents as variables to measure enterprise innovation.

4.1.3 Coal company performance variables

At present, for studying the variables related to enterprise performance, scholars mainly use the return on total assets or return on net assets as the relevant indicators of enterprise performance level. For example, China's scholars Cui Zhixia (2021) used return on total assets as a corporate performance variable[15]. That is, because the assets of coal enterprises are mainly composed of coal mines, and the coal mines owned by different listed companies lead to differences in the profitability of coal mines due to different resource endowments. For the study of corporate performance of mining industry, this paper adopts net profit as a measure of corporate performance. Although this indicator is slightly insufficient, it is the most intuitive for enterprise performance.

4.1.4 Control variables

This paper focuses on the impact of environmental regulation on enterprise innovation and enterprise performance, but the factors affecting enterprise innovation and enterprise performance are not limited to environmental regulation. Therefore, it is necessary to add control variables in the empirical analysis and model validation to reduce the experimental error so as to view the experimental results more objectively.

Since mining industry belongs to the heavy asset industry, fixed assets account for the main part in the balance sheet accounts. In addition, the main income of the coal company comes from coal mining and sales, so the enterprise's investment in fixed assets affects the future performance of the enterprise to a certain extent. Therefore, this paper selects the investment in fixed assets as a control variable.

4.2 Econometric modelling

This paper focuses on the impact of environmental regulation on enterprise innovation and enterprise performance. In studying the impact of environmental regulation on enterprise innovation, the explanatory variables are enterprise innovation index, the explanatory variables are environmental regulation intensity and enterprise net profit, as well as the control variable is enterprise fixed asset investment. When measuring the impact of environmental regulation on enterprise performance, the explanatory variables are enterprise performance. The explanatory variables are environmental regulation intensity and enterprise innovation index. The control variable is enterprise fixed asset investment. In addition, the proportion of enterprise R&D investment in operating income, the proportion of R&D personnel in the number of employees and the number of enterprise patents as a component of the enterprise innovation index, in order to avoid the randomness of the weight given to the entropy method for the processing of the above variables, so as to output the enterprise innovation index. Finally, due to the time series data involving multiple objects, it is necessary to use the panel model to deal with the relevant data.

4.3 Sample selection and data sources

This paper selects the sample data of A-share listed coal companies in Shanghai and Shenzhen for the seven-year period of 2018-2022 as the research object. The main source of data involved in this paper is the Tonghuashun ifind database, in which the enterprise performance, enterprise innovation data are from the annual reports published by each listed company. In this paper, 38 A-share coal listed companies are selected. In order to ensure the scientific nature of the sample data, the sample data screening process is as follows.

1) Screening samples of coal listed companies in the Shenwan industry

2) Excluding IPO samples after 2016

3) Excluding samples of non-disclosed environmental protection tax data

4) Excluding the sample of listed coal companies with ST or *ST after 2016

5) Excluding samples with incomplete financial data or environmental investment data

There are three main reasons for the screening conditions. Firstly, 2016 being the end point of the downward coal price cycle, it is possible that the increase in coal prices in the subsequent period may delay the firms' problems in the downward cycle, leading to the emergence of the firms' problems in the subsequent upward cycle. Secondly, the funds raised from the IPO could potentially lead to firms having more funds to invest in R&D, thus affecting the results of the experiment. Finally, environmental protection tax as an embodiment of environmental regulation, it is not possible to determine whether environmental regulation has an impact on firms as environmental protection tax has not been disclosed by the sample firms over a period of time.

In order to ensure the scientificity and reliability of the data, 21 relevant samples that do not meet the above requirements were excluded, and 17 qualified samples were finally identified in accordance with the requirements of comprehensive indicators and data consistency. 425 relevant data that meet the

ISSN 2616-5902 Vol. 5, Issue 23: 20-32, DOI: 10.25236/AJBM.2023.052304

requirements. After the completion of sample screening, the table 5 lists companies meet the requirements.

Table 5: Stock Codes and Names of Screened Sample Companies

Stock codes	Security name
600123.SH	Lanhua Sci-tech Venture
600188.SH	Yankuang Energy
600348.SH	Huayang Shares
600395.SH	Panjiang Shares
600508.SH	Shanghai Energy
600740.SH	Shanxi Coking
600792.SH	Yunnan Coal Energy
600971.SH	Hengyuan Coal Power
600997.SH	Kailuan Shares
601011.SH	Protherm
601101.SH	Haohua Energy
601666.SH	Pingmei Shares
601699.SH	Lu'an Environmental Energy
601898.SH	Zhongmei Energy
000723.SZ	Meijin Energy
000937.SZ	Hebei Energy
000983.SZ	Shanxi Coking Coal

4.4 Process of empirical analysis

4.4.1 Entropy value method arithmetic process

This paper selects the total R&D investment, the number of R&D personnel and the number of company patents of listed company samples as the indicators of enterprise innovation. By using the entropy value method to scientifically assign the weights occupied by each indicator during 2018-2022, avoiding the randomness of weight assignment. The results of entropy value method can be seen in the table 6.Subsequently, the entropy value method is used to process the results. Finally, the results are summed up to get the comprehensive index- enterprise innovation index.And the results of enterprise innovation index can be seen in the table 7.

Table 6: Calculation results of entropy value method

Item	**The information entropy value e**	**Information utility value d**	**Weighting (%)**
Total R&D investment as a percentage of operating revenue (2018)	0.722	0.278	51.049
Number of R&D staff as a percentage (2018)	0.908	0.092	16.826
Total number of company patents (2018)	0.825	0.175	32.125
Total R&D investment as a percentage of operating revenue (2019)	0.796	0.204	40.236
Number of R&D staff as a percentage (2019)	0.872	0.128	25.248
Total number of company patents (2019)	0.825	0.175	34.516
Total R&D investment as a percentage of operating revenue (2020)	0.809	0.191	40.701
Number of R&D staff as a percentage (2020)	0.884	0.116	24.705
Total number of company patents (2020)	0.838	0.162	34.594
Total R&D investment as a percentage of operating revenue (2021)	0.856	0.144	34.287
Number of R&D staff as a percentage (2021)	0.886	0.114	27.178
Total number of company patents (2021)	0.839	0.161	38.535
Total R&D investment as a percentage of operating revenue (2022)	0.875	0.125	30.828
Number of R&D staff as a percentage (2022)	0.887	0.113	27.768
Total number of company patents (2022)	0.832	0.168	41.404

Table 7: Comprehensive evaluation score of enterprise innovation index

Security name	Comprehensive evaluation (2018)	Comprehensive evaluation (2019)	Comprehensive evaluation (2020)	Comprehensive evaluation (2021)	Comprehensive evaluation (2022)
Lanhua Sci-tech Venture	0.153	0.163	0.171	0.146	0.148
Yankuang Energy	0.346	0.378	0.409	0.505	0.557
Huayang Shares	0.074	0.092	0.102	0.108	0.088
Panjiang Shares	0.199	0.354	0.331	0.249	0.284
Shanghai Energy	0.285	0.340	0.302	0.233	0.232
Shanxi Coking	0.160	0.123	0.093	0.113	0.154
Yunnan Coal Energy	0.244	0.367	0.356	0.380	0.397
Hengyuan Coal Power	0.870	0.829	0.664	0.663	0.588
Kailuan Shares	0.050	0.057	0.089	0.098	0.120
Protherm	0.103	0.152	0.162	0.138	0.142
Haohua Energy	0.518	0.545	0.542	0.437	0.436
Pingmei Shares	0.219	0.285	0.306	0.292	0.272
Lu'an Environmental Energy	0.443	0.519	0.388	0.598	0.530
Zhongmei Energy	0.441	0.531	0.551	0.576	0.596
Meijin Energy	0.008	0.020	0.046	0.157	0.092
Hebei Energy	0.105	0.150	0.173	0.138	0.237
Shanxi Coking Coal	0.119	0.162	0.161	0.186	0.305

4.4.2 Impact of environmental regulation on enterprise innovation

On the basis of the above data, this paper uses SPSS software to process the above data using panel model in order to test the effect of environmental regulation, fixed asset investment on enterprise innovation. The table 8 records the p-value of three kinds of test.After F-test and Breusch-Pagan test, it is found that the p-value of random effect model (RE) and fixed effect model (FE) is less than 0.05. Both models are applicable. The results of the analysis can be seen in the table 9.

Table 8: Panel model results of the impact of environmental regulation on enterprise innovation

Type of test	Statistic	P	Conclusion
F-test	55.001	0.000***	FE model
Breusch-Pagan test	138.874	0.000***	RE model
Hausman test	0.379	0.944	RE model

Table 9: Stochastic model test results

FE model						
Variant	Ratio	Standard error	t	P	R^2	F
const	0.26	0.022	11.645	0.000***	within=0.208 between=0.133 overall=0.126	F=5.699 P=0.002***
Strength of environmental regulation	0.001	0.012	0.112	0.911		
Fixed-asset investment	0	0	0.57	0.570		
Net profit	0.001	0	3.641	0.001***		
Note: ***, **, * represent 1%, 5% and 10% significance levels, respectively.						

Comprehensive table 9 show that the P value of the effect of environmental regulation on enterprise innovation is 0.911, which shows that the effect of environmental regulation on enterprise innovation is not significant. The effect of the variable net profit on enterprise innovation is significant at the 1% level, indicating that enterprise performance has a facilitating effect on enterprise innovation. To enhance the persuasiveness of the random utility model, the results of the fixed effects model also support the above description.And the results of fixed effects model can be seen in the table 10.

Table 10: Fixed-effects model test results of the effect of environmental regulation on enterprise innovation

RE model						
Variant	Ratio	Standard error	t	P	R^2	F
const	0.258	0.043	6.013	0.000***	within=0.208 between=0.133 overall=0.127	F=6.338 P=0.001***
Strength of environmental regulation	0.002	0.013	0.166	0.868		
Fixed-asset investment	0	0	0.721	0.473		
Net profit	0.001	0	6.097	0.000***		
Note: ***, **, * represent 1%, 5% and 10% significance levels, respectively.						

4.4.3 Impact of environmental regulation on business performance

On the basis of the above data, this paper uses SPSS software for panel modelling of the above data and the results of the model test are can be seen in the table 11.

Table 11: Model test results of the effect of environmental regulation on firm performance

Type of test	Statistic	P	Conclusion
F-test	7.977	0.000***	FE model
Breusch-Pagan test	23.272	0.000***	RE model
Hausman test	-29.685	1.000	RE model
Note: ***, **, * represent 1%, 5% and 10% significance levels, respectively.			

By passing the F-test and Breusch-Pagan test, it was found that the p-value of the random effects model and the fixed effects model was less than 0.05 and both models were applicable.

Table 12: Fixed-effects model test results for the effect of environmental regulation on firm performance

FE model						
Variant	Ratio	Standard error	t	P	R^2	F
const	4.33	24.804	0.175	0.862	within=0.404 between=0.089 overall=0.153	F=14.709 P=0.000***
Strength of environmental regulation	-28.183	6.914	-4.076	0.000***		
Comprehensive evaluation score	259.919	71.384	3.641	0.001***		
Fixed-asset investment	-0.192	0.111	-1.725	0.089*		
Note: ***, **, * represent 1%, 5% and 10% significance levels, respectively.						

The results of the model in the table 12 show that the environmental regulation variable environmental regulation strength and environmental regulation variable comprehensive evaluation scores are significant at the 1% level and fixed asset investment is significant at the 10% level. To enhance the persuasiveness of the fixed utility model, the random utility model test results are as follows.

Table 13: Random utility model test results for the effect of environmental regulation on firm performance

RE model						
Variant	Ratio	Standard error	t	P	R^2	F
const	55.252	15.694	3.52	0.001***	within=0.157 between=0.429 overall=0.273	F=10.141 P=0.000***
Strength of environmental regulation	-36.476	12.575	-2.901	0.005***		
Comprehensive evaluation score	93.377	35.863	2.604	0.011**		
Fixed-asset investment	0.378	0.197	1.916	0.059*		
Note: ***, **, * represent 1%, 5% and 10% significance levels, respectively.						

The experimental results in the table 13 illustrate that the environmental regulation variable environmental regulation intensity is significant at the 1% level. The enterprise innovation variable comprehensive evaluation score is significant at the 5% level, and the control variable fixed asset investment is significant at the 10% level. The results of the above two models indicate that the effect of environmental regulation intensity on firm performance is facilitative. The enterprise innovation has a facilitative effect on firm performance.

5. Conclusion and Recommendation

5.1 Conclusion

(1) When studying the effect of environmental regulation on enterprise innovation, the current data cannot prove the effect of environmental regulation on coal enterprise innovation. That is to say, the effect of environmental regulation on coal enterprise innovation is neutral, and the effect of enterprise performance on enterprise innovation is promoted. Meanwhile, the effect of environmental regulation on coal enterprise performance is also facilitating. This suggests that the effect of environmental regulation on coal enterprise performance is not mediated by the effect on enterprise innovation. It is possible that environmental regulation optimises the competitive landscape of the mining industry, which in turn affects coal firm performance. In addition, other possibilities remain. The ratio of enterprise R&D investment to operating revenue. The ratio of R&D personnel to all employees and the number of patents are still insufficient to fully reflect the enterprise innovation capability. It is possible that enterprises may adopt new technologies and equipment to improve their original production efficiency, thus significantly increasing their profitability during the coal price increase cycle.

(2) According to the official website of Shanxi Provincial Government, the official website of Shaanxi Provincial Government, the official website of Inner Mongolia Autonomous Region Government, and the official website of Xinjiang Uygur Autonomous Region Government, the national coal production capacity will be withdrawn from a cumulative total of 981.3 million tonnes from 2016 to 2020, and coal belongs to the cyclical industry. According to the traditional supply and demand model, the withdrawal of coal production capacity has a certain impact on coal prices, and thus supply-side structural reform may have a positive effect on the mining industry and coal enterprise performance to a certain extent. More researchers are needed to study this issue more extensively.

(3) China's mining industry under the influence of industry supply-side reform and environmental regulation, the performance of coal enterprises has improved dramatically. Especially after the outbreak of the Russian-Ukrainian conflict in 2021, international energy prices rose sharply, and coal enterprises fully benefited from the increase in coal prices and the rapid increase in coal production, which made outstanding contributions to China's energy security and economic development.

5.2 Recommendation

(1) Based on China's resource endowment, the mining industry has assumed an important role in energy security. Although China has proposed to achieve the goals of "peak carbon dioxide emissions" and "carbon neutrality", the mining industry is still very important at a time when economic development is dependent on energy consumption. The mining industry is still very important. Relevant enterprises still need to improve enterprise innovation, reduce the impact of environmental pollution, improve production efficiency, and thus enhance enterprise performance.

(2) At present, China's environmental governance relies mainly on laws and regulations, i.e., mandatory environmental regulation to influence the productivity of enterprises. In order to achieve the goals of "peak carbon dioxide emissions" and "carbon neutrality", the Government needs to raise the standards of pollution control for enterprises. At the same time, it needs to provide incentives for firms to combat pollution and to encourage firms to improve their R&D capabilities and innovations in order to improve firms' performance through voluntary environmental regulation.

(3) A more thorough market-oriented reform of China's mining industry is being promoted. From the sample data, it can be found that most of China's coal enterprises are composed of state-owned enterprises. State-owned enterprises have a greater advantage in acquiring coal resources than private enterprises. The advantages of private enterprises should be utilised and private enterprises should be encouraged to participate in the operation of coal enterprises in order to enhance the efficiency of the enterprises. In addition, the relationship between the mining industry and the power industry, as well as the relationship

between the mining industry and the metallurgical industry, needs to be reformed more thoroughly in a market-oriented manner, taking into account both equity and efficiency, in order to avoid entering into a zero-sum game.

Acknowledgements

Funding project: General Project of Philosophy and Social Sciences of Guangdong Province "Research on the impact of heterogeneous environmental regulation on green technology innovation of enterprises in the Guangdong-Hong Kong-Macao Greater Bay Area and its countermeasures"(Granted No. GD21CLJ03).

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