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The Impact of The "Dual Carbon" Target on China's Coal Industry Stock Prices--Analysis Based on The Double Difference Method

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Abstract. The proposal of "dual-carbon" target has far-reaching impacts on the coal industry and its stock market. This paper takes the data of China's A-share coal listed companies in Shanghai and Shenzhen from 2018 to 2023 as samples, takes the proposal of "dual-carbon" target as an exogenous event, and uses double-difference model to conduct regression analysis to study the impact of "dual-carbon" target on the stock price of China's coal industry. The results show that the introduction of the "dual carbon" target has a significant negative impact on the stock price of China's coal industry, and the results are still significant after the parallel trend test, the placebo test, and the test of excluding the year of policy promulgation. Based on this, recommendations are made for the government, regulators, coal industry enterprises and investors to jointly promote the development of the "dual-carbon" policy and the transformation and upgrading of the coal industry.

Keywords: "dual-carbon" target; coal stock prices; double-difference method; parallel trend test; placebo test.

1. Introduction

At present, the climate issue has become a common challenge to mankind. The General Secretary Xi Jinping proposed a "dual-carbon" goal at the 75th session of the United Nations General Assembly on September 22, 2020, which was reiterated at the Climate Ambition Summit in December 2020. This not only reflects China's responsibility on the international stage, but also demonstrates the urgency of environmental governance. While China is the world's largest coal consumer, the coal industry, as China's traditional energy pillar industry, occupies an important position in the national economy. However, due to the high carbon emission characteristics of coal, this industry is facing great challenges under the "dual-carbon" goal. With the gradual implementation of the "dual-carbon" policy, the valuation of the coal industry has been suppressed, and its share price has been constrained despite the rise in coal prices against the backdrop of tight supply and demand. Therefore, based on the data of China's A-share listed coal companies in Shanghai and Shenzhen from 2018 to 2023, this paper adopts a double-difference model to study the impact of the "dual-carbon" target on the stock price of China's coal industry, and based on the conclusions of the study, we further give policy recommendations to better promote the development of the "dual-carbon" policy and the transformation and upgrading of the coal industry.

This paper analyzes the impact of the "dual-carbon" target on the stock prices of China's coal industry, which not only reveals the mechanism of policy changes on the industry's market performance, but also provides useful references for investors and policy makers. For investors, understanding the impact of the policy on the industry's stock prices can help them formulate scientific investment strategies, reduce investment risks and improve investment returns. For policy makers, the findings of this paper can help assess the effects of policy implementation and optimize policy design, thus promoting the green transformation of the coal industry and achieving the coordinated development of economy, society and environment.

2. Literature review

2.1. Current status of domestic and international research

In the domestic and international markets, the stock price of the coal industry is affected by a variety of factors, including macroeconomic policies, industry policies, and changes in market supply and demand. In foreign countries, many scholars pay attention to the impact of energy transition on the coal industry, XiaoY et al. (2019) put forward the concept and technological framework of "multi-energy integration" to realize the complementary integration of multiple energy sources through technological innovation [1]. Based on the concept of multi-energy integration, CaiR et al. (2022) proposed a multi-energy integration technology system based on the four main lines of clean and efficient utilization of fossil energy and coupled substitution, non-fossil energy multi-energy complementation and scale application of industrial low-carbon and zero-carbon process reengineering, and digital and intelligent integration and optimization, and four platforms of syngas/methanol platform, energy storage platform, hydrogen platform, and carbon dioxide platform [2].

In China, with the proposal of "dual-carbon" target, the coal industry is facing the pressure of transformation, and the related studies are gradually increasing. Based on the dual governance perspective of central government and local government, Wang Xilian and Zhang Jiaru (2023) constructed an evolutionary game model of low-carbon transformation of coal enterprises, and used system dynamics to simulate its stabilization strategy dynamically, and the results showed that the behavioral strategies of the central government, local government, and coal enterprises fluctuated repeatedly, and there was no evolutionary stabilization strategy [3]. Qi Peng and Sun Xiaoru (2024) constructed a new type of performance appraisal indexes to optimize the performance appraisal system of coal enterprises by using the key performance indicator (KPI) method and hierarchical analysis (AHP) method, and highlighting the "dual-carbon" orientation on the basis of the traditional indexes [4]. Zu Binghui and Li Changsong (2024) studied the carbon emission reduction path of coal production enterprises under the background of "dual-carbon" from the aspects of coal production equipment, coal production technology, logistics and personnel management, and enterprise carbon emission capture and storage technology [5].

2.2. Research on the impact of macroeconomic policies on coal stock prices

Regarding the research on the impact of monetary policy on coal stock prices, Zhu Xiaofeng and Yang Youming (2021) studied the impact of the withdrawal of loose monetary policy in the United States on the market of coal and other commodities and examined their prices [6]. Meng Jun et al. (2016) took the long-term downturn of the coal market and the seven national adjustments of monetary policy in 2015 as the background, and carried out scientific data analysis and law exploration on the more significant fluctuation changes of coal industry related stocks [7]. Zhang Zhimin and Zhou Gong (2016) empirically test the shock effects of major domestic and international shock factors on energy price volatility, and find that money supply is the most important factor affecting domestic energy prices [8].

Regarding the research on the impact of interest rates and exchange rates on coal stock prices, Nie Rui et al. (2019) found that during the Bush and Obama administrations, the U.S. coal fixed asset investment was negatively correlated with China's coal prices, the U.S. coal tax revenues, the U.S. CAPP coal price and the WTI crude oil spot price were positively correlated with China's coal prices, and the impact of the U.S. dollar exchange rate on China's coal prices was gradually weakened[9]. Based on the econometric study of EGARCH-Copula model, Wang Qian and Lu Jingjing (2018) found that the impact of the RMB exchange rate on the pilot carbon market shows significant regional differences: there is a significant negative impact on the carbon price in Tianjin, a significant positive impact on Beijing, Shanghai and Shenzhen, and a weaker positive impact on Hubei and Guangdong; The impact of carbon price on Beijing and Shanghai showed a significant up-tail correlation, and that on Guangdong showed a down-tail correlation [10].

Regarding the research on the impact of policy uncertainty on coal stock prices, Bianlu et al. (2024) used TVP-VAR model and wavelet coherence analysis to study the impact relationship between climate policy uncertainty and the prices of three traditional international energy products, coal, crude oil, and natural gas, and found that there is a time-varying relationship between the prices of the three representative energy products and the climate policy uncertainty index that interacts with each other, and presents significant positive and negative alternating differential characteristics[11]. Jia Xianmin and Wang Xilian (2017) constructed a coal intertemporal optimal mining model on the basis of comprehensive consideration of various policy uncertainties, applied VC visual programming, numerical analysis and other methods, and simulated and predicted China's coal mining production sub-scenarios [12].

2.3. Research on the impact of industry policies on coal stock prices

Regarding the research on the impact of industry tax policies on coal stock prices, Li Kun et al. (2024) conducted research on the coal industry in Liupanshui City from the perspective of taxation, analyzed the current situation of the development of the coal industry in Liupanshui City, and put forward countermeasures and suggestions to promote the development of the coal industry chain [13]. Fan Jingli et al. (2018) carried out a quantitative study on the impact of coal resource tax from volume-based to ad valorem on coal enterprises, and found that the coal mining industry lost the most after the policy change [14].

Regarding the research on the impact of financial industry policies on coal stock prices, Li Chenxia et al. (2024) used the entropy method to measure the green financial development and energy consumption structure transformation based on the panel data of 30 provinces and regions in China from 2011 to 2020, and found that the green financial development and the transformation of the energy consumption structure have significant spatial agglomeration characteristics, both of which show positive spatial self-Correlation[15]. Gu Xiao and Ma Qiang (2024) empirically analyzed the impact of green financial policies on energy structure, and found that green financial policies significantly optimized energy structure, and there was a spatial spillover effect, which could simultaneously improve the energy structure of the local and other regions [16].

Regarding the research on the impact of energy policies on coal stock prices, Yao Jiahan and Sun Xiaohan (2022) used a dynamic CGE model and found that under carbon emission constraints, domestic coal and oil prices would rise rapidly in the short term due to supply control superimposed on cost promotion, and in the long term, prices would gradually go down in volatility and eventually stabilize [17]. Jiao Bing and Xu Chunxiang (2023) analyzed the impact of the five-year energy development plan on the transformation and upgrading of China's energy industry through a double-difference model with two levels: the national group and the western group [18].

Regarding the research on the impact of other industry policies on coal stock prices, Yu Zuo et al. (2024) categorized the capacity removal policies into mergers and acquisitions (M&A) restructuring and capacity restriction from the perspective of partial ownership among competing firms, and empirically demonstrated that M&A restructuring has a significant positive effect on coal prices, and capacity restriction strengthens the positive effect of M&A restructuring on coal prices [19]. Sun Chunsheng (2017) used principal component regression analysis to analyze the effect of coal industry policies from four levels of economic benefits, safety benefits, ecological and environmental benefits and social benefits, and found that the development plan has a large negative impact on the economic benefits of the coal industry [20].

2.4. Literature review and innovations

Existing literature mainly focuses on the impact of macroeconomic policies such as monetary policy, interest rate and exchange rate, and policy uncertainty, as well as industry policies such as tax policy, financial industry policy, energy policy, etc., on coal stock prices, while the "dual-carbon" target is seldom studied as an exogenous policy variable. Therefore, this paper takes the proposal of "dual-

carbon" goal as an exogenous event, takes Shanghai and Shenzhen A-share listed companies as the samples, and uses double-difference model to conduct regression analysis to study the impact of the proposal of "dual-carbon" goal on the share price of the coal industry.

Based on the above reflections and analysis, the marginal contributions of this paper may be: (1) Based on the panel data of Chinese A-share listed companies in Shanghai and Shenzhen from 2018 to 2023, a double difference model is used to study the correlation between the "dual-carbon" target and the share price of the coal industry, which broadens the quantitative research to the field of "dual-carbon" policy and provides an empirical basis for better promoting the implementation of the "dual-carbon" goal. (2) Based on four aspects: macro, meso, micro and investor sentiment, a theoretical research framework on the role of "dual-carbon" policy in coal stock price is constructed, which is a useful supplement to the existing research on the factors influencing stock price volatility, and provides a theoretical basis for identifying the combination of the policy and the stock market.

3. Theoretical analysis and research hypothesis

The " dual-carbon" target, i.e., the carbon peak and carbon neutral target, is a major strategic initiative of the Chinese government to address the challenge of climate change, aiming to promote green, environmentally friendly and low-carbon living concepts and practices. This goal has not only profoundly reshaped China's macro-regulation of resources, meso-industry layout, and micro-enterprise business environment, but also directly touched investors' market sentiment, which has led to significant fluctuations in the share price of the coal industry. The basic influence mechanism is shown in Fig. 1.

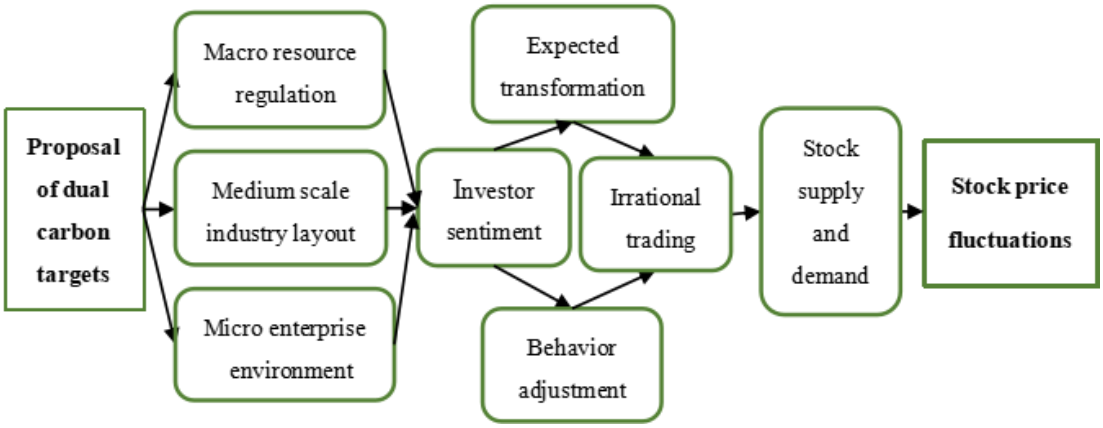

Fig. 1 Mechanism of the impact of the "dual-carbon" target on the share price of the coal industry

3.1. Transmission of the "dual-carbon" target to macro-resource regulation

The implementation of the "dual-carbon" target has first changed China's macroeconomic environment. Through a series of policy instruments, such as the establishment of the carbon trading market, the levy of carbon tax, the promotion of green financial policies, etc., the government has guided the resources from the high-emission, high-energy-consumption traditional energy industry to the low-carbon, environmentally friendly new energy industry, and thus promoted the optimization and upgrading of the economic structure. This policy-oriented signal conveys to the market that the new energy industry will gain more development opportunities, while the coal industry may gradually lose its market advantage.

3.2. Transmission of the "dual-carbon" target to the meso-industry layout

The implementation of the "dual-carbon" target has changed China's meso-industry layout then. The promotion of green financial policies has provided more financial support for the new energy and clean energy industries, allowing these industries to develop rapidly, which in turn constitutes a competitive pressure on the coal industry; the tax directly increases the cost of using fossil energy

such as coal, making the profit space of the coal industry squeezed, while the revenue from the carbon tax can be used to support the development of the new energy and clean energy industries, which further accelerated the pressure to transform the coal industry. Investors therefore expect that coal enterprises will face greater competition, transformation and cost pressure in the future and profitability may further decline. Such expectation has led to a decline in investor confidence in the coal industry, which in turn has a negative impact on the stock price.

3.3. Transmission of the "dual-carbon" target to microfirm fundamentals

The implementation of the "dual-carbon" target will inevitably have a greater impact on the real economy, affecting the fundamentals of the micro-enterprises, especially the main business of coal and other traditional energy industry chain of listed companies.

On the one hand, it is manifested in the impact on enterprise management strategy. The proposal of "dual-carbon" target makes coal enterprises need to carry out energy structure adjustment, reduce the dependence on coal, increase the proportion of clean energy, in order to realize this goal, coal enterprises need to increase the investment in technological innovation, however, technological innovation requires time and capital investment, and there is a certain degree of risk, so it may have short-term fluctuations in the share price of coal enterprises. However, technological innovation requires time and capital investment and involves certain risks, so it may cause short-term fluctuations in the share price of coal companies.

On the other hand, it is manifested in the impact on the financial situation of enterprises. The implementation of the "dual-carbon" target makes it necessary for coal enterprises to invest more funds in the construction of environmental protection facilities, technological transformation and the development of clean energy, etc., and these inputs increase the operating costs of the enterprises, which in turn affects their profitability, and the rise in costs may lead to a fall in the share prices of coal enterprises.

3.4. Transmission of the "dual-carbon" target to investor sentiment

The implementation of the "dual-carbon" target has sent certain signals to investors through macroeconomics, meso-industries, and micro-companies, triggering fluctuations in investor sentiment.

On the one hand, the implementation of the "dual-carbon" target has made investors worried about the future prospects of traditional energy industries such as coal, and they are concerned about the risks and challenges that these industries may face during the transformation process, which in turn reduces their willingness to invest in these industries. On the other hand, the adjustment of investor behavior is manifested in the fact that with the promotion of the "dual-carbon" target and the rapid development of the new energy industry, investors are more inclined to invest in the new energy and clean energy industry, which in turn constitutes an investment pressure on the traditional energy industry, such as coal.

Under the uncertainty of the effect of the implemented policy on the stock price, there is a difference in the perception of different buyers and sellers, and the decisions made are not the same, with some investors arbitrarily deciding on their trading behavior, and others following the actions of others. When the stock market receives news of a policy, investors may make biased decisions because they tend to be irrational, and more irrational investors will follow the market and blindly engage in buying and selling behaviors, resulting in a short-term change in supply and demand for coal stocks, and investors will reduce the demand for holding stocks in the coal industry, which further accelerates the decline in the share price of coal stocks.

Based on the above theoretical analysis, Hypothesis 1 is proposed:

H1: The implementation of the "dual-carbon" target has had a negative impact on coal sector stock prices.

4. Data description and sample selection

4.1. Data description

In order to study the impact of the "dual-carbon" target on the share price of the coal industry, it is necessary to analyze the overall operation of the stock market and the trend of the share price of the coal industry, and then select a representative coal company for specific analysis. In this paper, we download the relevant data of the specified stocks from Resset and Wind database, including CSI 300 index, stock data and financial indicators of the listed companies in the coal industry, the specific indicators include the date, closing price, turnover rate, price-to-book ratio, consumer price index, company's total assets, total assets, net profit margin, return on net assets, growth rate of operating income, asset-liability ratio, etc. The data are analyzed and analyzed in the following way.

Whether the "dual-carbon" target will have a long-term policy effect on the coal industry stock price is analyzed using the double-difference method. This paper takes the time when the "dual-carbon" target is put forward as the node, and selects 2018-2020 as the years before the "dual-carbon" target is put forward, and 2021-2023 as the years after the implementation of the policy to conduct empirical research, so the time span of the data is from January 2, 2018 to December 29, 2023.

Based on the consideration of the impact of the sample data on the empirical results of the article, this paper carries out the following processing of the acquired data: (1) in order to ensure the stability of the empirical results, the listed companies with the time nodes after 2018 are excluded; (2) for the listed companies with the missing or abnormal relevant variables, the interpolation method is applied to pre-process the data. All data processing and empirical studies involved are through Excel and Stata software.

4.2. Sample selection

4.2.1. Selection of policy information

On September 22, 2020, China solemnly announced for the first time at the United Nations General Assembly its "dual-carbon" target, a commitment that is divided into two milestone phases: the first phase aims to achieve carbon peaking by 2030, marking the point at which China's carbon dioxide emissions will reach a historical peak, and then enter a steady downward trajectory without further growth. The second phase aims to achieve carbon neutrality by 2060, signifying that China will ensure that the country's net CO_2 emissions will reach zero by then through a series of measures such as planting trees and improving energy efficiency, so as to achieve a harmonious balance with the natural world. This move not only signals that China's economy is accelerating its transformation towards a new era of green and low-carbon development, but also signals that a far-reaching and thorough energy revolution is quietly taking place behind the scenes.

The proposal of "dual-carbon" target will undoubtedly have a far-reaching and significant impact on listed companies in the traditional energy industry of coal. In view of this, this paper selects 2020, the historically significant year when China first proposed the "dual-carbon" target, as the starting point for analysis, with the aim of exploring and verifying whether the proposal of the "dual-carbon" target has had a significant impact on the volatility of the share prices of listed companies in the coal industry. The purpose of this analysis is to investigate and verify whether the introduction of the "dual carbon" target has a significant impact on the share price volatility of listed companies in the coal industry.

4.2.2. Selection of sample stocks

In this paper, 75 listed companies in the coal industry are selected as the total sample based on the classification criteria of the coal industry.In the process of empirical analysis using the double difference method, in order to assess the impact of the policy, it is necessary to compare the acceptance of the difference of individual results, and in the realistic analytical situation, the comparative analysis of the treatment group and the control group can scientifically peel off the natural trend of the change, and then estimate the long-term impact of the policy, therefore In this

paper, based on this sample of 75 listed companies in coal industry, they will be divided into treatment group and control group.

Listed companies whose stock closing price on the last trading day of 2020 is below the quarter quartile are treated as the treatment group, and listed companies above the three-quarter quartile are treated as the control group, and finally 38 listed companies in the coal industry are retained as the stock sample, and the grouping results are shown in Table 1.

Table1 List of Sample Listed Companies

Stock name (treatment group)	**Stock code (treatment group)**	**Stock Name (Control Group)**	**Stock code (control group)**
Itai B shares	900948	Northern International	000065
Yongtai Energy	600157	Panjiang Corporation (PJSC)	600395
Cloud Computing	600725	China National Fire (Norwegian corporation)	000933
Yuanxing Energy	000683	Blue Flame Holdings	000968
Zhongfu Industry	600595	Shanxi Coal International	600546
Huaihe Energy	600575	Ningbo United	600051
Huadian Energy	600726	Zhengzhou Coal and Electricity	600121
Shandong Mining Machinery	002526	Shaanxi Coal Industry	601225
Antares Group	600408	Yu Energy Holdings	001896
Inner Mongolia Huadian	600863	Yankuang Energy	600188
New Daizhou A	000571	Shanghai Energy	600508
Chitinization	600227	TBEA (Tianjin Economic Development Area)	600089
Guangdong Hongyuan A	000573	Ordos, region of Inner Mongolia administered as a prefecture-level city, and a people of the region	600295
Guangdong and Guangxi Energy	600256	Diantou Energy	002128

Stock name (treatment group)	Stock code (treatment group)	Stock Name (Control Group)	Stock code (control group)
Tiandi Technology	600582	Huaibei Mining	600985
Huayin Power	600744	Yulong Shares	601028
Yatai Group	600881	Qingdao CTS	300208
Xinhuzhongbao	600208	Kinon Technology	603113
Xinji Energy	601918	China Shenhua (abbr.)	601088

In order to compare the stock price movement trends of the treatment and control groups, the closing prices of the stocks in the two groups were averaged and logarithmized, and the overall movement trends are shown in Fig. 2. The closing prices of the two groups of listed companies are basically the same from 2018 to 2019, and after September 2020 the two curves show a clear difference in the trend of change, which provides a preliminary basis for the treatment and control groups to be comparable.

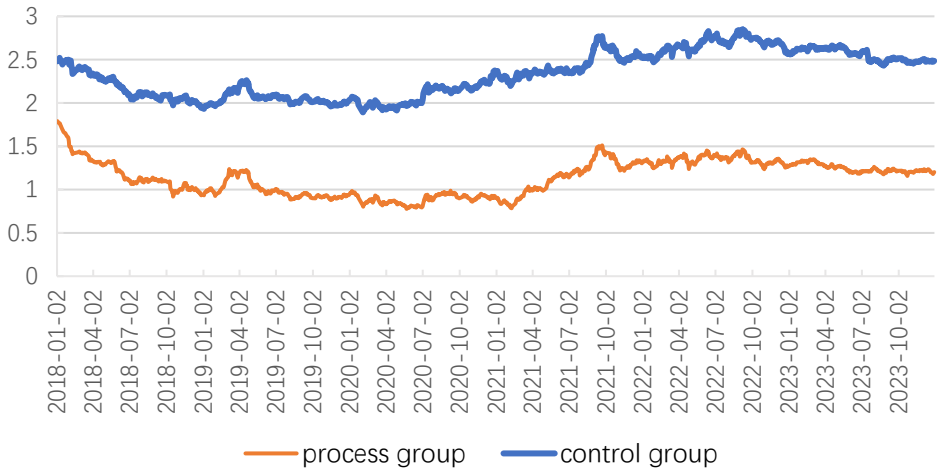

Fig. 2 Closing price trends for treatment and control groups

5. Empirical study on the impact of dual carbon policies on coal industry stock prices

5.1. Overall analysis of the broader market from 2018 to 2023

Given that stock price fluctuation is a cumbersome and complex process, in order to better reflect the operation of the stock market and fluctuation trends, but also in order to correctly guide the investment behavior of investors, the stock price index is usually used to indicate the high and low prices of the stock market and the trend of stock price fluctuations, the CSI 300 index is composed of the largest

and most representative of the Shanghai and Shenzhen A-shares 300 stocks with good liquidity to comprehensively reflect the overall performance of the Shanghai and Shenzhen A-share markets. Therefore, this paper selects CSI 300 index as the representative stock index for analysis and research.

In order to visually analyze the situation of China's stock market before and after the introduction of the dual-carbon target, the closing price data of the CSI 300 index for 1,457 trading days from January 2, 2018 to December 29, 2023 are used to perform statistical analysis and draw line graphs, and the data are obtained from the CEIC database.

Fig. 3 CSI 300 Index 2018-2013 Chart

As shown in Fig. 3, the CSI 300 Index experienced an up-and-down and volatile market environment between 2018 and 2023. Of these years, 2019 and 2020 were the more significant years of growth, while 2018, 2022 and 2023 showed varying degrees of decline.The closing price of the CSI 300 showed a downward trend throughout 2018, with a decline of 25%, with a maximum closing price of 4,365.39 points and a minimum closing price of 3,010.65 points, continuing to decline throughout the year without any significant rollover point in time The CSI 300 Index realized a relatively large increase in 2019, with a gain of 37.00%. The maximum closing price of 4196.71 points, the minimum closing price of 2966.54 points, the beginning of 2019 began to rebound, the whole year shows an upward trend. 2020 continues to maintain good growth momentum, CSI 300 index rose 27.24%, the maximum closing price of 5211.29 points, the minimum closing price: 3574.90 points, the beginning of 2020 began to rise, the whole year maintains the growth trend In 2021, the CSI 300 Index has slowed down, but still maintains a positive growth rate of 25.34%. The maximum closing price reached 4940.92 points in December 2021, and the minimum closing price reached 4435.79 points in January 2021, with an overall increase throughout the year, but with a small pullback at the end of the year. 2022 saw a pullback in the market, with the CSI 300 Index falling by 16.91%, with the maximum closing price reaching 4169.01 points in March 2022, and the minimum closing price reaching 3410.31 points in October 2022, with a trend of growth throughout the year. 2022 The market performed better from the beginning to the middle of the year, but started to decline after that, especially in the second half of the year.2023 saw the CSI 300 index fall by 11.38% for the whole year. Despite a sharp rally at the beginning of the year, the market then started to fall volatility and the index closed at 3431.11 at the end of the year, showing typical bear market characteristics.2023 reached a maximum close of 4263.07 in March and a minimum close of 3431.11 at the end of the year.2023 saw the market have a sharp rally at the beginning of the year, but then it entered into a state of volatility and decline, especially in the second half of the year.

Combining the above changes in the closing price of the CSI 300 Index from 2018 to 2023, it is analyzed that the closing price of the CSI 300 Index experienced a relatively large increase in 2019 and 2020, and the closing price of the CSI 300 Index remained stable or showed a different degree of decline in other time periods, and whether the movement trend of the stock market of the coal industry is the same as that of the CSI 300 Index The next step needs to be verified.

5.2. Empirical results and analysis of the double-difference method

5.2.1. Model setup

The double difference method is used to estimate the long-run effect of the dual carbon policy on the share price of the coal industry, and Model 1 is set up in this paper:

$$RT_{it} = \beta_0 + \beta_1 DID_{it} + \beta_2 Treat_i + \beta_3 Time_t + \beta_4 X_{it} + \varepsilon_{it} \quad (1)$$

In Model 1, RT is the daily return rate of the stock price of listed coal enterprises, which is obtained by dividing the difference between the closing price and the opening price of the day. DID is the multiple difference term obtained by the interaction between treat and time. Treat is the sample studied and is a dummy variable. When treat=1, it represents the processing group; when treat=0, it represents the control group; Time is the Time dummy variable; when Time=1, it indicates that the policy has occurred; when time =0, it indicates that the policy has not occurred. X is a set of control variables, including: consumer price index (CPI), book-to-market ratio (BM), the inverse of the price-to-book ratio, enterprise size (SIZE), the contents are total assets of listed enterprises, stock turnover ratio (TR), daily return rate of CSI 300 Index (MI), return on equity (ROE), return on total assets (ROA), operating income growth rate (Growth), asset-liability ratio (LEV). ε is the disturbance term, i is the stock sample of the listed company, and t is the specific time.

As the share price of the coal industry is affected by macroeconomic factors, the industry's share price will change with the economic situation. The consumer price index is an important macroeconomic indicator that reflects the basic situation of consumer price changes across the country, so the consumer price index is used to represent the impact of macroeconomic factors on the share price of the coal industry. Book-to-market ratio reflects the results of listed enterprises and the investment value of stocks, which can be decomposed into tangible returns reflecting the fundamentals of the enterprise and intangible returns reflecting the subjective expectations of investors, the scale of the enterprise represented by the total assets of the company can be used as an important indicator to measure the wealth of the enterprise and the management of the company, and the rate of change in turnover is an important indicator reflecting the strength of the liquidity of the stock, so using the book-to-market ratio of the enterprise's size, the change in turnover rate, the rate of return on net assets The return on net assets, return on total assets, etc. represent the development prospects of the enterprise and the investment value of the stock, reflecting the enterprise's income and investment risk. The stock price of Coal industry is affected by the whole stock market at the same time, and the stock samples belong to Shanghai and Shenzhen, so the return of CSI 300 index is chosen as the representative of the broader index to measure the impact of the stock market in a large number of market indexes.

For data consistency all variables are controlled for annual data and thus panel data are constructed. Table 2 shows the descriptive statistics of the main variables in this paper, theRT The volatility ranges from -1.92 to 1.37, indicating a high degree of uncertainty and volatility in the market's response to coal stocks.RT The mean value is close to zero, indicating that the average daily return of coal stocks is close to zero during the observation period.MI The volatility ranges from -30.58 to 30.8, which indicates high volatility in the stock market as a whole, theMI The mean value of -2.92 indicates that the performance of CSI 300 index tends to fall during the observation period.CPI The relatively small fluctuation of from 1202.9 to 1234.8 indicates that the consumer price is relatively stable.TR The fluctuation range of the CSI 300 is extremely large, from 7.18 to 2888.77, indicating that the liquidity of the stock market varies greatly.

Table 2 Meaning of main variables and descriptive statistical analysis

variant	Variable Definition	N	Mean	SD	Min	Max.
RT	Ln(day's closing price/opening price)	228	0.01	0.4	-1.92	1.37
MI	Ln(day's closing price/opening price)	228	-2.92	23.07	-30.58	30.8
CPI		228	1221.3	11.03	1202.9	1234.8
SIZE	Ln(total assets of the company)	228	23.88	1.44	19.65	27.17
BM	1/ P/E ratio	228	0.81	0.44	0.03	2.78
TR		228	311.94	330.99	7.18	2888.77
ROA	Net profit/total assets	228	3.7	7.58	-33.57	26.5
ROE	Net profit/total assets	228	-0.24	50.28	-500.3	54.95
Growth	(Current operating income - prior period operating income) /prior period operating income	228	11.41	53.4	-77.83	547.37
LEV	Total liabilities/total assets	228	55.22	19.31	6.75	111.31

5.2.2. Benchmark regression results

Table 3 presents the results of the benchmark regressions based on the double-differenced model. Column (1) controls only for individual fixed effects and time fixed effects; column (2) adds a series of firm-level control variables to column (1), but controls only for individual fixed effects; and column (3) introduces both control variables, individual fixed effects, and time fixed effects.

The results show that the coefficients of the core explanatory variables are significantly negative at the 1% level in all cases, indicating that the implementation of the dual-carbon policy significantly reduces the stock price of the coal industry, a result that supports this paper's research hypothesis H1. The implementation of the "dual-carbon" target has a dual impact on enterprises. First, this goal pushes coal companies to adjust their energy structure, reduce their reliance on coal and increase the proportion of clean energy. In order to realize this goal, coal enterprises need to increase investment in technological innovation. However, technological innovation requires time and capital investment and carries certain risks, which may cause short-term fluctuations in the share price of coal companies. Secondly, the implementation of the "dual carbon" goal also affects the financial status of enterprises. In order to meet the environmental protection requirements, coal enterprises need to invest more money in the construction of environmental protection facilities, technological transformation and the development of clean energy, etc., which increases the operating costs of the enterprises, and thus affects the profitability of the enterprises. Rising costs may lead to a decline in the share price of coal companies.

Table 3 Benchmark regression results

variant	(1)	(2)	(3)
DID	-0.1643**	-0.1987***	-0.2253***
	(0.0851)	(0.0676)	(0.0862)
MI		0.0077***	0.0075***
		(0.0014)	(0.0015)
CPI		-0.0050***	-0.0053***
		(0.0024)	(0.0026)
SIZE		0.0722	0.0725***
		(0.0252)	(0.0252)
BM		-0.2391***	-0.2401***
		(0.0741)	(0.0741)
TR		0.0003	-0.0003***
		(0.0001)	(0.0004)
ROA		-0.0092***	0.0091***
		(0.0041)	(0.0041)
ROE		-0.0003***	-0.0003***
		(0.0004)	(0.0004)
Growth		0.0008***	0.0006***
		(0.0006)	(0.0017)
LEV		-0.0032***	-0.0032***
		(0.0016)	0.0016
constant term (math.)	-0.0078	0.0751***	4.9476
	(0.0524)	(0.0211)	(3.1854)
control variable	clogged	be	be
time fixed effect	be	clogged	be
individual fixed effect	be	be	be
observed value	228	228	228
Adjustment $R2$	0.0090	0.3313	0.3318

Note: *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively, with standard errors in parentheses.

5.2.3. Robustness tests

(1) Parallel trend test

Benchmark regression results show that the coefficient of the core explanatory variable is significantly negative, indicating that the enactment of the dual-carbon policy reduces the stock price of the coal industry. In order to ensure that the interaction term coefficients can accurately reflect the treatment effects brought about by the implementation of the policy, this paper carries out the parallel

trend and policy dynamic effect test for the experimental group and the control group. Referring to the method of Liu Qiang et al. (2020) [21], in order to avoid multicollinearity, the previous period of the policy implementation (i.e., 2019) is taken as the base period, and the event study method is used to conduct the test and construct model 2:

$$RT_{it} = \beta_0 + \sum_{t=2018,t\neq2019}^{2023} \beta_t DID_{it} + \beta_2 Treat_i + \beta_3 Time_t + \beta_4 X_{it} + \varepsilon_{it} \quad (2)$$

where$Time_t$ is a time dummy variable that takes the value of 1 when the year to which the sample belongs ist takes the value of 1 when the sample belongs to, otherwise it takes the value of 0. The meanings of the other items are the same as in model (1). Fig. 4 shows the results of parallel trend hypothesis testing and policy dynamic effect analysis with daily stock returns of coal industry as explanatory variables.

It can be found that the coefficient of the interaction term in model (2)β_t are insignificant until 2020, indicating that before the enactment of the dual-carbon policy, the trend of stock price changes in the treatment group and the control group is consistent and not significantly different, i.e., the parallel trend hypothesis is satisfied.Since 2020, the stock price level of the treatment group declines more significantly compared to that of the control group firms. This difference indicates that the implementation of the dual-carbon policy has a significant negative impact on the share price of coal companies.

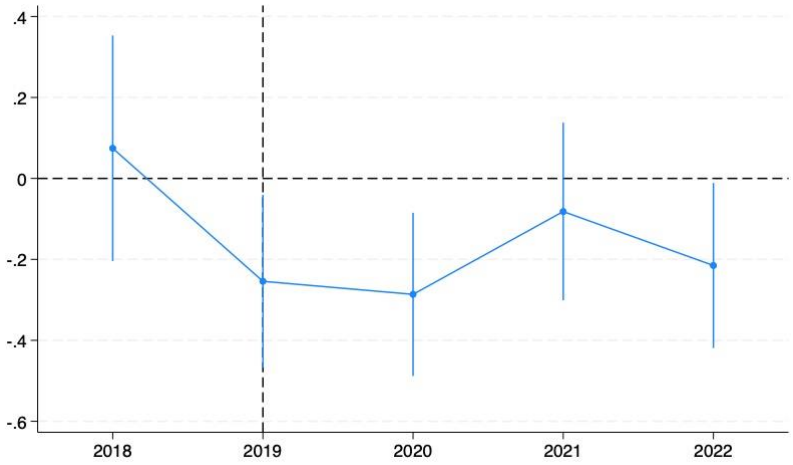

Fig. 4 Parallel trend test results

(2) Placebo testing

To avoid confounding effects of other unobservables synchronized with the dual-carbon policy on the estimation results, this paper conducts two placebo tests. The first is a time counterfactual test, i.e., the policy shock is advanced by one year and set to 2019. Accordingly, the time dummy variable takes the value of 0 before 2019 and 1 after 2019. If the aforementioned policy effects are caused by other factors, the regression results of the core explanatory variables should remain significant. According to Table 4, the coefficients of the core explanatory variables are no longer significant, indicating that the benchmark regression results can reflect the dual-carbon policy effects and are not the result of other factors or enterprises' early responses.

(3) Excluding the year of policy enactment

Table 4 Placebo test results

Outcome var.	RT	S. Err.	|t|	P>|t|
Before				
Control	-0.008			
Treated	0.015			
Diff(T-C)	0.023	0.058	0.40	0.693
After				
Control	0.133			
Treated	-0.008			
Diff(T-C)	-0.141	0.130	1.09	0.277
Diff-in-Diff	-0.164	0.142	1.16	0.248

Note: *, ** and *** denote significant at 10%, 5% and 1% levels, respectively.

The dual-carbon policy was issued and implemented in 2020, so the relevant data for 2020 has both pre- and post-policy implementation information. In order to prevent possible estimation bias, this paper excludes the sample data of the year of policy promulgation and re-regresses the regression test, and the results are shown in Table 5. The results are shown in Table 5. It can be seen that the exclusion of the data related to the year of policy promulgation does not affect the regression results, and the coefficients of the core explanatory variables are still significantly negative at the 1% level, and the conclusion that the dual-carbon policy significantly reduces the stock price of the coal industry remains unchanged.

Table 5 Results of excluding the year of policy enactment

Outcome var.	RT	S. Err.	|t|	P>|t|
Before				
Control	-0.090			
Treated	0.031			
Diff(T-C)	0.121	0.065	1.06	0.289
After				
Control	0.133			
Treated	-0.008			
Diff(T-C)	-0.141	0.113	3.27	0.001***
Diff-in-Diff	-0.437	0.116	3.76	0.000***

Note: *, ** and *** denote significant at 10%, 5% and 1% levels, respectively.

6. Research findings and policy recommendations

6.1. Conclusions of the study

Since 2020, when China clearly put forward the "dual-carbon" goal of achieving carbon peak by 2030 and carbon neutrality by 2060, the national level has responded quickly to form the "1+N" "dual-carbon" policy system, aiming to comprehensively promote the green and low-carbon transformation of the economy and society. This policy framework not only emphasizes the optimization and adjustment of the energy structure, but also pays special attention to the transformation path of coal, a traditional energy industry. Based on the data of A-share listed companies in Shanghai and Shenzhen between 2018 and 2023, this study adopts a double-difference model to analyze the impact of the proposed "dual-carbon" target on the stock price of the coal industry.

The study found that the introduction of the "dual-carbon" target had a significant negative impact on the stock prices of China's coal industry. This implies that as the state attaches more importance to energy conservation, emission reduction and green low-carbon development, market participants are cautious about the future development prospects of the coal industry, which leads to pressure on the stock prices of related companies. Further, the validity of the model is ensured by the parallel trend test, i.e., the development trend of the treatment group and the control group is consistent without policy intervention; the placebo test excludes other unobserved factors from interfering with the results; and the test excluding the year of policy promulgation verifies the robustness of the conclusions, suggesting that, even if the fluctuation of the market's reaction at the time of the initial announcement of the policy is not taken into account, the "dual-carbon" policy is not a good choice for the future development of the coal industry. The negative impact of the "dual-carbon" target on coal industry stock prices remains significant in the long run, even without considering the volatility of the market reaction when the policy was first announced.

6.2. Policy recommendations

In view of the above conclusions, this paper puts forward the following policy recommendations in order to effectively respond to the challenges posed by the "dual-carbon" goal and promote the smooth transformation and sustainable development of the coal industry:

(1) Government level: The government should continue to introduce more policies and measures to support the transformation and upgrading of the coal industry, such as providing financial subsidies, tax exemptions, technical support, etc., so as to reduce the cost of transformation of enterprises; to establish and improve the carbon emissions trading market, so as to incentivize enterprises to reduce their carbon emissions through the market mechanism, and at the same time, to explore the innovation of green financial products, so as to provide channels for financing the transformation of coal enterprises; to strengthen the coordination of the "dual carbon" policy with other economic policies to ensure that the realization of the policy objectives will not have an impact on economic stability.

(2) At the level of regulators: Strengthen the supervision of the transformation process of the coal industry, ensuring that environmental standards are strictly enforced during the transformation process, and at the same time provide industry guidance and consulting services to help enterprises rationally plan the transformation path; requiring coal enterprises to disclose more transparently information about their carbon emissions, progress of the transformation process, and environmental risks, so as to enhance market confidence and protect the interests of investors.

(3) At the enterprise level in the coal industry, enterprises should take the initiative to adapt to the requirements of the "dual-carbon" goal, increase investment in R&D, explore clean and efficient use of coal technology, develop new energy business, and achieve diversified development; optimize the production process, improve the efficiency of resource utilization, and reduce waste, and at the same time, strengthen the training of employees to enhance their understanding and participation in the green and low-carbon development.

(4) Investor level: Investors should fully recognize the impact of the "double carbon" target on the long-term development of the coal industry, rationally assess the investment risk and avoid blindly following the trend of investment; actively look for and invest in those coal enterprises that actively respond to the national policy, have a clear plan for transformation and good prospects for transformation, so as to share the long-term benefits brought by the transformation.

References

[1] Xiao Y,Peng ZL,He JD,etal.Science and technology innovation promotes construction of new national energy system (in Chinese) .Bull ChinAcadSci,. 2019,34:385-391.

[2] Cai R,Zhu HX,Li WJ,etal.Development path of energy science and technology under "dual carbon "goals:Perspective of multi-energy system integration (in Chinese). Bull ChinAcadSci,2022,37:502-510.

[3] Wang Xilian,Zhang Jiaru. Research on the motivation and strategy of low-carbon transformation of coal enterprises under the dual-carbon target[J]. Coal Technology,2023,42(07):247-250.

[4] Qi Peng, Sun Xiaoru. Optimization of performance appraisal system in coal enterprises under the background of "double carbon"[J]. Journal of Mining Science,2024,9(01):126-134.

[5] Zu Binghui, Li Changsong. Study on the carbon emission reduction path of coal production enterprises under the background of "double carbon"[J]. Journal of Mining Science,2024,9(03):464-474.

[6] Zhu Xiaofeng,Yang Youming. Preventing the impact of the exit of U.S. loose monetary policy on the commodity market[J]. Price Theory and Practice,2021,(08):12-17+34.

[7] Meng Jun,Zhang Feifei,Du Wei. Research on the volatility of coal industry stocks under the national loose monetary policy[J]. China Coal,2016,42(04):16-21.

[8] Zhang Zhimin,Zhou Gong. Research on the impact effect of monetary policy on energy price volatility in China[J]. Modern Management Science,2016,(03):12-14.

[9] Nie Rui,Wang Jia,Qian Xiangyan. Research on the impact of U.S. energy policy change on China's coal price[J]. Price Monthly,2019,(01):1-9.

[10] WANG Qian,LU Jingjing. The shock effect of RMB exchange rate on China's carbon price--Based on the perspective of regional differences[J]. Journal of Wuhan University (Philosophy and Social Science Edition),2018,71(02):157-165.

[11] Jia Xianmin,Wang Xilian. Forecast of China's coal mining production under the influence of uncertainties[J]. Statistics and Decision Making,2017,(01):90-92.

[12] BIAN Lu,ZHANG Chentao,ZHANG Jiangpeng. A study on the relationship between climate policy uncertainty and the impact of traditional international energy prices based on TVP-VAR model and wavelet coherence analysis[J]. Resource Development and Markets,1-13.

[13] Li Kun, Qian Qinglan, Ma Jihong, Zhang Yutang, Xu Man, Zhang Yongkang, Zhou Yun, Zhao Yongqiang, Xiang Mei, Xia Bangsheng, Lv Zhaohu, Ao Lishu. Research on High-Quality Development of Coal Industry Chain under the Perspective of Taxation--Based on the Survey of Liupanshui City, Guizhou Province[J]. Tax Research,2024,(04):64-68.

[14] FAN Jingli,HOU Yunbing,KONG Linshi. Research on the impact of coal resource tax policy on coal enterprises and social economy[J]. Coal Engineering,2018,50(09):177-180.

[15] Chenxiao Li,Kelly Liu,Sirui Ma. Spatial effects of green finance development on the transformation of provincial energy consumption structure[J]. Economic Geography,2024,44(08):148-157.

[16] Gu Xiao, Ma Qiang. Research on the threshold and spatial effect of green finance on energy structure under the goal of "double carbon"[J]. Hubei Social Science,2024,(02):101-109.

[17] Yao Jiahan,Sun Xiaohan. Research on the impact of carbon emission constraints on China's macro effects and energy prices--Based on the perspective of playing the superimposed advantages of fiscal policy and financial support[J]. Financial Theory and Practice,2022,(05):38-47.

[18] Jiao Bing, Xu Chunxiang. "Evolutionary Logic and Future Trends of China's Energy Policies since the 13th Five-Year Plan--Based on the Perspective of the Energy Revolution Toward the Goal of "Dual Carbon"[J]. Journal of Xi'an University of Finance and Economics,2023,36(01):98-112.

[19] Yu Zuo,Shi Junrong,Luo Tianyu. Partial Ownership among Competitive Firms, Capacity Reduction Policy and Abnormal Coal Prices in China[J]. Economics(Quarterly),2024,24(03):861-877.

[20] Sun Chunsheng. Evaluation analysis of coal industry policy effect based on principal component regression analysis[J]. Industrial Engineering and Management,2017,22(06):154-160+168.

[21] Liu Qiang, Wang Weinan, Chen Hengyu. A study on the impact of the implementation of the Green Credit Guidelines on the innovation performance of heavily polluting enterprises[J]. Research Management, 2020,41(11).