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The impact of carbon risk on stock prices of energy companies --Empirical research based on investors' concerns

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Abstract

With the gradual implementation of environmental governance under the "Double Carbon" goal, whether an enterprise can actively fulfill its environmental protection responsibility is related to the sustainable development ability of the enterprise and affects the attention of investors. This paper uses the Baidu search index as an indicator of investor attention in the Chinese stock market, and builds a VAR model to study carbon risk based on the closing prices of 20 representative energy company stocks and the daily trading price data of eight carbon emissions exchanges. And investors are concerned about the impact on the stock prices of energy companies. The results show that there is a long-term mutual influence relationship among carbon risk, investors' attention and stock prices of energy companies. For a long time, there is a two-way Granger relationship between investor attention, carbon risk, and energy company stock prices; the impulse response shows that investor attention has an impact on carbon risk, carbon risk on energy company stock prices, and energy company stock prices. Stock prices have a positive impact on carbon risk. Finally, this paper puts forward corresponding suggestions for the investment decisions of Chinese investors, the strategic development of energy companies and the development of the carbon emission trading market.

Keywords

Carbon risk; stock price; VAR model; Baidu index.

1. Introduction

Carbon trading has become the main means of combating climate change and is considered the most cost-effective carbon emission reduction tool (Bu Wenke and Zhao Mengen, 2020). In July 2021, my country's unified national carbon emission trading market will fully launch carbon trading (Li Jiangtao and Tao Siyuan, 2022). On January 2, 2023, the "Report on the First Compliance Cycle of my country's Carbon Emissions Trading Market" pointed out that in the first compliance cycle of China's carbon emissions trading market economy, the total volume of carbon emissions trading was 7.661 billion shares, and the total trading volume of allowances was 179 million Ton, the operation of the trading market is stable and orderly, and the transaction price is rising steadily. The establishment of the national carbon exchange means that my country's carbon emissions trading market has completed the initial structural construction, the effect of the value discovery mechanism has been initially reflected, the awareness of corporate emission reduction and the technical level have been significantly improved, and the expected goals have been achieved. With the formation and improvement of China's carbon emission trading market and the continuous increase in the cumulative number of carbon emission allowance transactions, the value of the carbon trading market and the interaction with other markets have attracted more and more attention. Energy companies have also begun to pay attention to China's carbon emissions. The impact of the trading market

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on corporate emission benefits, investment value, and corporate development (Zhao Lingdi and Wang Haixia, 2019).

Energy company stock prices are affected by oil prices, coal prices, investor behavior and other macro factors. Investors' risk aversion mentality will improve investors' information gathering behavior (Lemieux J et al, 2011; Abbas A E et al, 2013), thus affecting investors' investment decisions. In the Internet age, search engines are one of the important ways for people to obtain information. Therefore, the keyword search volume can reflect to a certain extent the importance investors attach to a certain information. In the domestic market, due to the large number of individual investor groups, there is a highly coupled relationship between the two major groups of stockholders and netizens (Xu Qifa et al., 2017). Compared with institutional investors, the heterogeneous beliefs of individual investors have a more significant impact on the stock prices of energy companies (Liu Yan and Zhu Hongquan, 2018). According to statistics in 2022, the Baidu search engine occupies 75.63% of China's domestic search engine market share and 7.44% of the global market share. At the same time, it can also reflect the search engine data through the Baidu Index, which can better reflect the domestic individuals in China. investor situation. Although many research results have confirmed the effect of investor attention on stock price fluctuations in the stock market, few studies have applied investor attention to the impact of energy companies' stock prices and carbon risks.

The main contributions of this paper are as follows: first, to provide relevant suggestions for Chinese investors to make rational investment decisions; second, to cultivate a sound carbon price formation mechanism, and to effectively use the resource allocation effect of the capital market to drive energy companies to save energy and reduce emissions Improve the industrial structure and actively promote the technological innovation and application of carbon finance; third, call on energy companies to vigorously promote technological innovation and thereby promote the development of their own companies and the development of my country's carbon emission trading market; fourth, through the introduction of investors' attention In order to increase the participation in carbon emissions trading and enrich carbon emission rights The activity of the trading market.

2. Literature review

The existing literature mainly focuses on the positive relationship between the search volume index and the stock price, the negative relationship between the search volume index and the estimated price, and the interaction between the search volume index and the stock price. Da et al. (2011) proposed for the first time to use the Google search volume index (SVI) as a proxy for investor attention indicators to join the model. The research shows that the rise of the Google search volume index indicates that the stock price will rise in the next half month and the price will decline within the year. However, not every country uses Google as the main Internet search engine. Taking my country as an example, the share of Baidu Internet search engine is much larger than that of Google Internet search engine. Therefore, studies by scholars at home and abroad have shown that using the Baidu search index can better reflect the importance that Chinese netizens and investors attach to relevant information. Yu Qingjin and Zhang Bing et al. (2012) used the Baidu search index as a proxy for the variable of investors' limited attention. The research shows that investor attention is positively correlated with stock prices and will reverse in a short period of time. Investor attention on non-trading days will also affect The stock price for the next trading day. Chen Xiaohong et al. (2016) and Chen Zhiyuan et al. (2016) respectively found a positive correlation between the Baidu index and turnover, closing price and yield, but some researchers came up with opposite conclusions. For example, Preis et al. (2013) and Curme et al. (2014) found that an increase in the search volume of related words is often accompanied by a decrease in the corresponding stock price. Dong et

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al. (2020) found that the relationship between investor attention and stock prices is not a one-way correlation but an interactive relationship. In view of this, this paper introduces the Baidu index as a proxy for investor attention to explore the impact of changes in investor attention on carbon risk and the future volatility and correlation of energy company stock prices, so as to explore the development of China's carbon trading market.

To sum up, at the level of research content, a few articles have explored the relationship between carbon prices and stock prices, but there is a lack of empirical research specific to the overall impact on the stock prices of energy companies. In addition, the existing literature mainly takes the EU market as an example, and there are relatively few studies on the carbon emission trading markets in the eight major provinces and cities in China. At the level of research methods, in view of the immature mechanism of my country's corporate environmental information leaks, the literature usually selects the carbon emission exemption as a proxy variable for carbon risk. Immunity is used as a proxy variable to obtain a small sample of stocks. Therefore, this paper selects the stocks of energy companies as proxy variables. Although there are a large number of literatures showing the relationship between investor attention and stock returns, there are few articles that combine investor attention with the VAR model to explore its interaction with carbon risk and energy company stock prices. relation. Therefore, under the background of China's emphasis on low-carbon economy and ecological environmental protection, this paper explores the impact of carbon emission price on the stock price of energy companies based on investors' attention, and provides evidence from China for carbon finance from both theoretical and empirical perspectives.

3. Variable selection and data sources

3.1. Variable selection

3.1.1. Interpreted variables

Stock prices of energy companies are most sensitive to fluctuations in carbon prices, so this paper uses stock prices of energy companies as explanatory variables. The CSI 800 Index is recognized as an index that can reflect stock market fluctuations, so this article selects 20 energy industry stocks to reflect the overall performance of energy company stock prices. The market value of the 20 energy companies ranks high, and they come from different regions in my country, with high representation. The time span of data selection is from June 26, 2019 to November 7, 2022, with a total of 808 daily stock closing price data. The daily closing prices of 20 representative energy companies in my country are preprocessed as explained variables, and the data comes from the Wind database.

3.1.2. Explanatory variables

The carbon emission trading price is introduced as an explanatory variable. The fluctuation of carbon price represents the fluctuation of carbon risk. This paper refers to the relevant literature at home and abroad to select the daily closing price of the carbon emission trading market as the quantification object of carbon risk. This paper selects the eight major carbon emission trading markets in various provinces and cities in my country as the research object, including the newly opened Fujian carbon emission trading market. The time span of data selection is from June 26, 2019 to November 7, 2022. In this paper, the daily carbon trading closing prices of the eight major carbon emission trading markets in my country are weighted and averaged and defined as carbon risk for research. The data Source Wind database.

3.2. Data source and preprocessing

In this paper, the stock prices of the selected 20 energy companies and the carbon trading prices of my country's eight major carbon emission rights exchanges are weighted and averaged, and the daily stock price data that can represent the industry and the data that represent the daily

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price of carbon trading are obtained. The Baidu index of all keywords is weighted and averaged to obtain the average Baidu index representing the degree of attention of investors. Since the data is not stable, the logarithms of the three time series are taken respectively, and three new series of lncarbon, lnstock, and lnbaidu are obtained. The fluctuation diagram of the new series is shown in Figure 1.

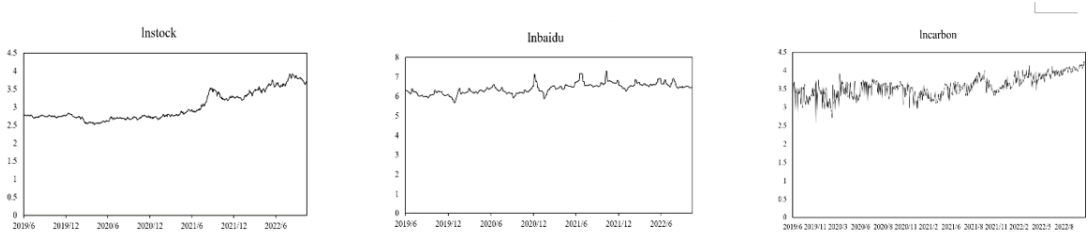

Figure 1 New sequence fluctuation diagram

4. Empirical analysis

4.1. Stationary test and lag order selection

4.1.1. Stationarity test

The stationarity of all variables needs to be tested, and the VAR model can only be established after the stationarity of all data passes. Then, all variables are tested for unit root to verify whether there is a unit root. If it is not stable, the non-stationary variables are differentially processed, and the variables are all stable after processing. As shown in Table 1, after taking the first-order difference, the four variables dlncarbon, doil, dcoal, and dlnstock are all stable, and a VAR model can be established.

Table 1: Robustness test result table

Variable	ADF	p	Steady state
lncarbon	-3.21023	0.0831	unstable
dlncarbon	-19.9394	0.0000**	stable
lnbaidu	-4.428990	0.0003	stable
btr	-5.62502	0.0000**	stable
oil	-2.26524	0.4521	unstable
doil	-27.2222	0.0000**	stable
coal	-1.86094	0.6737	unstable
dcoal	-28.3998	0.0000**	stable
lnstock	-2.01671	0.5908	unstable
dlnstock	-27.7469	0.0000**	stable

Note: ** indicates that the null hypothesis is rejected at the 5% level.

Statistically describe the selected research variables. It can be seen from the standard deviation that the degree of dispersion of the sample is small and the data is relatively stable after processing, as shown in Table 2.

Table 2: Statistical description table of final selected variable data

Variable	N	mean	std	min	max
dlncarbon	808	0.000806	0.182643	-1.08462	1.101595
dlnstock	808	0.001162	0.022361	-0.08447	0.078791
lnbaidu	808	6.415096	0.265264	5.671358	7.266079

ISSN: 2664-9640

4.1.2. Selection of Lag Order

The determination of the lag order is very important in the establishment of the VAR model. Generally, the AIC criterion (AIC) and the SC criterion are used to determine. Using Eviews9.0 software to build a VAR model with a lag period from 0 to 9 for the data, and use the criteria to select the best lag order.

It can be seen from Table 3 that the optimal lag order in the lag test is concentrated in lag four and lag five. By consulting the relevant literature, it is found that when the optimal lag order cannot be determined by referring to the AIC criterion and the SC criterion, the LR criterion and the HQ criterion can be referred to first. According to this criterion, it is judged that the optimal lag order of this model is 5th order. Therefore, this paper chooses the optimal lag order P=5, and establishes a VAR model with a lag of 5 periods, that is, VAR(5).

Table 3 :Lag order result table

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-180.864	NA	0.005418	0.457732	0.469455	0.462236
1	2231.583	4806.778	1.31e-05	-5.570921	-5.535752	-5.557410
2	2257.837	52.18051	1.23e-05	-5.626627	-5.568012	-5.604108
3	2277.138	38.26353	1.19e-05	-5.664927	-5.582866	-5.633401
4	2295.484	36.27827	1.15e-05	-5.700836	-5.595329*	-5.660303*
5	2300.013	8.93255	1.14e-05*	-5.702160*	-5.573206	-5.652618
6	2303.612	7.081455	1.15e-05	-5.701157	-5.548757	-5.642608
7	2304.808	2.346932	1.15e-05	-5.694138	-5.518292	-5.626582
8	2310.327	10.80275	1.15e-05	-5.697939	-5.498647	-5.621376
9	2315.694	10.48006*	1.15e-05	-5.701363	-5.478625	-5.615792

Note: * represents the optimal lag order determined under different criteria.

4.1.3. AR test

The passing of the AR test can prove that the model is stable and effective, so as to ensure the accuracy of further research. The AR test was carried out on the model, and the reciprocals of all AR unit roots were less than 1 and uniformly distributed in the unit circle with a radius of 1, so there was no unit root.

4.2. Empirical analysis based on VAR model

4.2.1. Model construction

Based on the previous variable setting, this paper establishes a VAR model to study the impact relationship between carbon risk and energy company stock prices based on the perspective of investor attention. The vector autoregressive model is a time series model that uses all current variables in the model to regress the lagged variables of all variables, and its expression is as follows:

$$yt=A1yt-1+...+Apyt-p+Bxt+\varepsilon t$$
$$t=1，2，...，T \quad (1)$$

In this paper: yt represents the stock price of energy companies, xt represents the degree of investor attention and carbon risk, p represents the lag order, t represents the number of research samples, and εt is the disturbance term.

4.2.2. Granger causality test

The Granger causality test was carried out on each sequence in the software environment of Eviews9.0, and the lag period was selected as 1~5. Table 4 shows that when the null hypothesis

ISSN: 2664-9640

is "the fluctuation of the stock price of energy companies will not cause changes in carbon risk", the p value of the Granger test is 0.006513<0.05, rejecting the null hypothesis that the fluctuation of the stock price of energy companies will cause carbon risk When the null hypothesis is "the fluctuation of carbon risk will not cause the stock price change of energy companies", the p value of Granger test is 0.008958<0.05, rejecting the null hypothesis that the fluctuation of carbon risk will cause the stock price change of energy companies. To sum up, there is a two-way causal relationship between the stock price of energy companies and carbon risk.

Table 4 :Granger causality test result table

Original hypothesis	F statistics	P value	Conclusion
Lnstock is not Granger Cause of lncarbon	0.66343	0.0065**	Reject
Lncarbon is not Granger Cause of lnstock	0.32862	0.0089**	Reject
Lnbaidu is not the Granger cause of lnstock	4.99862	0.0481**	Reject
Lnstock is not the Granger Cause of lnbaidu	1.29803	0.0262**	Reject
Lnbaidu is not Granger Cause of lncarbon	1.577728	0.1164**	Accept
Lncarbon is not Granger Cause of lnbaidu	1.41926	0.0214**	Reject

Note: ** indicates that the null hypothesis is rejected at the 5% level.

4.2.3. Impulse response

Perform impulse response processing on lncarbon, lnstock, and lnbaidu respectively. The impulse response is the impact on the current and future periods after adding a shock term to the random error term. It can be seen from Figure 2 that when the carbon risk is impacted by the stock price of energy companies, it responds immediately in the first period and reaches its peak in the fifth period. After the 5th period, it began to decline and gradually stabilized. When energy companies are impacted by carbon risks, they respond quickly in the first period and are on a continuous upward trend. This is related to factors such as the energy industry adopting energy conservation and emission reduction to reduce costs, updating production technology and equipment, and seeking other alternative energy sources. It showed a downward trend in the 5th period. This is because the transaction price of carbon emission rights increased, the cost of the energy industry increased, and the increase in the price of carbon emission rights affected investors' enthusiasm for investment in the energy industry. After the 6th period, it gradually stabilized. It shows that the price of carbon emission rights has a long time to influence the stock price of energy companies. When carbon risk is impacted by investors' attention, it responds quickly and reaches its peak in the first period. Since the sharp rise in investors' attention will have a significant short-term impact on carbon risk, the combined influence of other factors leads to a gradual decline after the second period. The upward trend continues from the fifth period, which is due to the long-term impact of investor attention on carbon risks. After being impacted by investors' attention, the stock prices of energy companies continued to rise in the first period. This is because investors' attention reflects investors' decision-making preferences, which directly affects the stock prices of energy companies.

To sum up, changes in energy company stock prices are closely related to carbon risk, fluctuations in investor attention, and also to their own fluctuations. However, on the whole, the impact of carbon risk on energy company stock prices has greater volatility.

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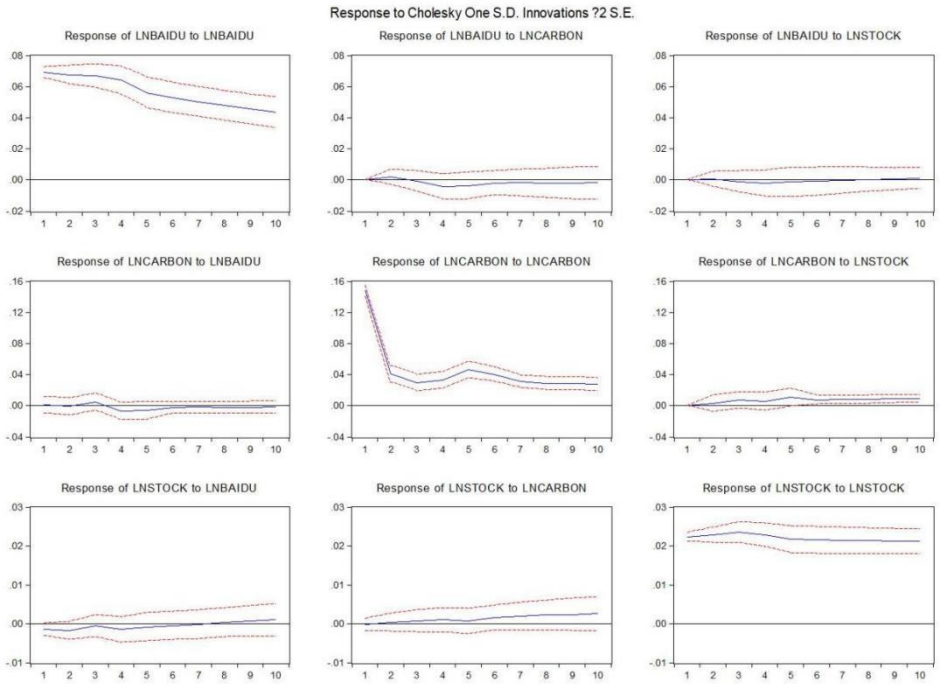

Figure 2: Impulse response result graph

4.2.4. Variance decomposition

Variance decomposition analysis of stock prices of energy companies. It can be seen from Table 5 that during the lag periods 1 to 10, the contribution of carbon risk to the stock prices of energy companies has been in an obvious and stable upward trend since the first lag period; From the third lag period to the ninth lag period, it is in a stable upward trend, and from the third lag period to the ninth lag period, it is in a state of fluctuation, and from the ninth lag period to the tenth lag period, it continues to rise steadily; the average price index of coal From the first lag period to the tenth lag period, the stock prices of energy companies are in an obvious and stable upward trend; the contribution of the turnover rate of energy companies to the energy company stock prices is at a level from the first lag period to the tenth lag period. Clearly a steady upward trend.

Table 5: Variance decomposition result table

period	Sd	lnstock	lncarbon	Oil	Coal	BTR	lnbaidu
1	0.02241	99.5875	0.011062	0	0	0	0.38549
2	0.03203	99.4839	0.01641	2.69432	0.11214	0.05981	0.46015
3	0.03976	99.6104	0.045164	3.70870	0.385362	0.11749	0.30997
4	0.04586	99.5548	0.083828	3.65540	1.550681	0.17261	0.32185
5	0.05075	99.5920	0.084549	3.57322	2.362657	0.23284	0.28292
6	0.05515	99.5673	0.150844	3.5832	2.919749	0.29610	0.24360
7	0.05918	99.5153	0.239051	3.65015	3.302463	0.38017	0.21224
8	0.06296	99.4434	0.335859	3.73010	3.557193	0.48519	0.19159
9	0.06651	99.3628	0.428613	3.84517	3.747266	0.56537	0.18196
10	0.06988	99.2636	0.52719	3.96220	3.888859	0.62795	0.18217

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5. Conclusion

This paper selects the daily data of closing prices of energy companies and carbon emission trading prices from June 26, 2019 to November 7, 2022, as well as data from the official website of Baidu Index, to construct the relationship between stock prices of energy companies, carbon risk, and investor attention. The VAR model is used to empirically study whether carbon risk has an impact on the stock prices of energy companies. The results show that carbon risk and investor attention have a significant impact on energy company stock prices, and there is a long-term interaction between energy company stock prices and carbon risk, and carbon risk is the most important factor affecting energy company stock price fluctuations. In addition, through the impulse response, this paper finds that the changes in the stock prices of energy companies are closely related to the fluctuations in carbon risks. When the carbon price fluctuates, the stock prices of energy companies first fluctuate sharply and then gradually stabilize. The stock prices of energy companies are also related to their own fluctuations, but on the whole, the impact of carbon risk on the stock prices of energy companies has greater fluctuations. Variance decomposition is carried out to study the contribution of random shocks of each variable. The study finds that crude oil price and coal price will also have a significant impact on energy company stock prices.

In view of this, the article puts forward the following suggestions: First, investors should be fully aware of the importance of reducing irrational investment in asset investment. The research in this paper shows that the attention from investors can reduce the information asymmetry between the stock market and the carbon market, and further prevent excessive fluctuations in stock prices. By adopting a standardized information disclosure system and a sound investor education system, investors are encouraged to make rational decisions in the investment process, reducing irrational market fluctuations and improving stock market pricing efficiency. Secondly, energy companies should vigorously promote technological innovation in order to achieve rapid development of energy transformation. Through empirical analysis, this paper concludes that energy companies' trading in the carbon trading market is an important way to help companies reduce emissions in the short term, and they still need to rely on high-energy-consuming companies to complete energy transformation in the long run. Thirdly, give full play to the important role of the government in the construction of the carbon trading market. Scientifically set carbon quotas to improve the efficiency of social resource allocation. Government departments can ensure the stable development of the carbon trading market by formulating policies and other means. The introduction of carbon quota policies must fully consider its impact on the national economy such as stock prices. In addition, government departments can also take measures such as changing the allocation quota and changing the auction ratio to stabilize the carbon trading market price. Finally, government departments should explore a reasonable carbon price in light of domestic reality. On the one hand, a reasonable carbon price will encourage enterprises to more actively realize low-carbon transformation; on the other hand, by absorbing more social capital into China's carbon trading market, it will further enrich my country's carbon trading market, thereby increasing the activity of the carbon trading market . Accelerate the development of my country's carbon emission rights exchange, and actively explore a reasonable carbon price that achieves the best energy-saving and emission-reduction effects in light of the actual market conditions of our country, and promote energy companies to be more active in low-carbon transformation. Government departments should pay attention to the signal effect of carbon price, and actively cultivate a sound carbon price formation mechanism and a unified national carbon emission trading market.

At this stage, the research on the forecasting ability of domestic network data is still in the preliminary exploration stage, and the text is just a preliminary attempt. Compared with how

to use complex models to predict investor attention, this research focuses on investor attention, carbon risk In terms of exploring the mutual influence relationship with the stock prices of energy companies, there is not much ink on the specific transmission mechanism in between. In the future, as the scale of my country's carbon market continues to expand and the subjects continue to diversify, the research on investor attention can be more perfect, including accurate quantification of attention. In addition, the risks brought about by climate change are also a topic of concern to the carbon market and energy companies. In the future, from the perspective of climate change and meteorological disasters, we can explore the internal mechanism of the interaction between carbon risks and energy company stock prices.

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