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Studies of the Relationship Between International Crude Oil Prices and Stock Prices of New Energy Companies and Investor Sentiment

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Abstract: This paper uses the daily data of the CSI Mainland New Energy Index, WTI crude oil price, and CSI 500 risk premium from January 2019 to September 2022 as samples to explore the interrelationship of the above variables using the Johansen cointegration test, Granger causality test, impulse response, and variance decomposition. The results show that in the short run, international crude oil price and risk premium have a significant effect on the share price of new energy companies; in the long run, global crude oil price cannot affect the share price of new energy companies, as well as international crude oil price and share price of new energy companies have a significant effect on the risk premium.

Keywords: CSI Mainland New Energy Index; WTI crude oil price; risk premium; investor sentiment

1. Introduction

As a non-renewable resource, crude oil plays an irreplaceable role in the political situation as well as in the standard of living of the population. However, in recent months, the international community has been less active in investing in crude oil exploration and development, which has affected crude oil production to some extent. China is amid an upswing in its manufacturing sector, with increasing industrialization and high demand for crude oil. However, China depends on global supplies for over 70% of its crude oil, which is a worrying but logical situation. Furthermore, as excessive use of fossil fuels emits harmful substances and poses a significant threat to natural disasters, people are becoming aware of the advantages of new energy sources as the concept of environmental protection spreads.

In recent years, new energy has become the focus of national strategic development and a hot stock market concept. Companies at home and abroad are going to develop new power, such as new energy vehicles, which has led to the size of the new energy market stocks being continuously expanded. It

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has been found through previous studies that crude oil and new energy can significantly affect market sentiment. However, market sentiment affects new energy stock prices and international crude oil prices, and do the original findings still hold over time? Therefore, this paper uses the CSI Mainland New Energy Theme Index (hereafter referred to as the new energy stock price proxy) from January 2019 to September 2022, the price of US West Texas light crude oil (WTI) denominated in RMB. The risk premium consists of the CSI 500 rolling P/E ratio and the 10-year Treasury yield as data samples to explore the relationship between the three and to provide an outlook for possible future research.

2. Literature Review

In recent years, with the development of the new energy securities market and the volatile rise in international crude oil prices, as well as the high level of investor concern for the new energy industry, several scholars at home and abroad have begun to focus on the relationship between new energy stock prices, international crude oil prices, unexpected events, and investor sentiment, with the following research results.

Compared to the studies on the relationship between international oil prices and the stock market, there are fewer studies discussing the relationship between global oil prices and stock market sentiment indices, and even fewer studies specifically analyzing the extent of the impact of global crude oil prices on the changes in China's stock market sentiment indices. Wang Jiayan [1] used principal component analysis to extract investor sentiment factors and subdivided the traditional sentiment variables to obtain the conclusion that there is a long-term equilibrium relationship between the volatility of international crude oil prices and Chinese stock market investor sentiment and that global crude oil prices hurt Chinese stock market investor sentiment. In the long run, the two tend to fluctuate inversely, and in the short run, they are positively correlated with each other in the initial period [1].

Based on the above study, Yi Shengkang [2] and Zhao Kun [3] introduce investor sentiment indicators, which can represent the consideration of irrational factors in the investment decision process and influence the final investment behavior of investors. It can more intuitively show the impact of international oil price fluctuations on China's stock market [2]. The latter is based on dynamic factor analysis, collecting traditional sentiment proxy variables such as network data and turnover rate to construct investor sentiment indicators [3]. The results show that investor sentiment has a positive impact on future stock market risk, and liquidity has a negative effect on future stock market risk. Thus although investor sentiment is positively related to liquidity, the two act in opposite directions. Whether investor sentiment is considered or not, international oil prices negatively impact the oil consumption sector and positively impact the new energy sector as a proxy [1-3]. Baffes points out that OPEC policy, geopolitical risk, and the strengthening of the US dollar are all strong drivers of crude oil prices, but the results are inconsistent. Zhou Minglei used the ARMAX model to obtain that unexpected events can significantly affect oil prices, and different unexpected events have other effects on oil prices [4]. Liu Qingfu et al. examined the impact effects of significant risk events on China's commodity futures market through a stochastic volatility model [5]. They found that economic circumstances, political events, and natural disasters significantly affect China's commodity futures returns and volatility. Chai et al. start from the equilibrium model of oil prices, which argues that unexpected events can break the equilibrium model of oil prices and cause significant fluctuations in oil prices.

Meanwhile, Li Zhuwei et al. findings show that changes in investor sentiment can cause fluctuations in the crude oil price index to a certain extent. However, when an external shock occurs, the shift in investor sentiment does not happen immediately, takes a reaction time, and only generates volatility in the short term, returning to its initial level in the long term. The volatility of the stock price index explains most of the changes in investor sentiment, with the USD/CNY exchange rate

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index in second place and the crude oil price index's volatility contributing the least to investor sentiment changes.

In international studies, Zhonglu Chen et al. have documented the volatility of five representative energy sources to predict assets in two energy markets by using four significant predictors simultaneously, namely VIX, GEPU, USEPU, and investor sentiment [6]. The study's results show that within-sample results indicate that the VIX significantly impacts the five energy assets. Only investor sentiment significantly positively impacts WTI oil futures and spots. Olusanya E. Olubusoye et al. conclude that each energy price is characterized by unique downward (price decline) and upward (price recovery) movements [7]. Moreover, Oluwasegun B. Adekoya showed that stock returns are more sensitive to uncertainty measures when market conditions are expected [8].

However, limited by the theoretical level, technical means, and data accuracy at the time of the paper's creation, the results derived from the final analysis may be biased. The conclusions of the research that lack timeliness may not apply to the current stock market and cannot suggest practical guidance for future generations. For example, although Wang Jiayan et al. considered the sentiment fluctuations of Chinese domestic investors in response to changes in international oil prices, the samples selected in their article are from April 2007, November 2012, and April 2015, which are outdated and cannot present the relationship between international oil prices and Chinese stock market investor sentiment today; in addition, the method used in constructing sentiment indicators is too single when collecting data, and it is too homogeneous, so the authority of the online platform is not guaranteed [2]. The statistical standards of the data are not consistent. Therefore, the limitations of the above-mentioned studies leave room for a more in-depth discussion in this paper.

This paper not only updates the data but also selects explicitly the time interval spanning the average year, the occurrence of the new crown epidemic, and the outbreak of the Russia-Ukraine war, which is more relevant and time-sensitive, and also uses Johansen co-integration test, Granger causality test, impulse response analysis, and variance decomposition in the empirical part to analyze the relationship between international crude oil prices, domestic new energy stock prices and domestic investor sentiment index. According to the observed results, China's new energy stock market has shown strong independence in recent years, and there is a relationship between active and passive influence with investor sentiment. However, chin financial trading market is unilaterally closed.

3. Empirical Method

3.1. Sample Selection and Data Description

(1) Company stock prices and international crude oil prices. Because the mainland new energy index has comprehensive coverage of the new energy industry chain, and the spot price of WTI crude oil has liquidity and high price transparency, this paper selects 000941 to measure the share price of new energy companies and the spot price of WTI crude oil as the fluctuation data of international crude oil price [9].

(2) CSI 500 rolling P/E ratio. The P/E ratio is chosen for risk premium calculation. However, the static P/E ratio reflects historical profits, and the static operating ratio will be undervalued if the company's performance declines. Rolling P/E ratios, on the other hand, are often projected based on the growth rate of profits and are more in line with investor sentiment and expectations.

(3) Ten-year Treasury bond yields. Long-term interest rates significantly impact the equity market, and their changes represent, to some extent, the risk appetite and expectations of financial market participants. There is a negative correlation between interest rates and stock prices. Investors will exit the stock market when interest rates rise and invest in the bond market instead. At the same time, interest rate changes affect a business's value through discounted cash flow valuation. A rise in interest rates will reduce a firm's valuation, and the share price will naturally fall. In the existing literature,

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Qing Zeng [10], Zhong Shi-he [9], and Moya- Martínez (2014), among others, consider the selection of long-term interest rates as one of the variables. Similarly, in this paper, the 10-year Treasury yield is chosen to measure long-term interest rates because the 10-year Treasury bond is the most liquid among medium- and long-term Treasury bonds; its yield is a better indicator of the expected trend of our economy [10].

(4) Risk premium. An indicator of the value for money of stocks and bonds is the risk premium, which measures the risk premium of stocks relative to bonds and is characterized by mean reversion. When supplies are cost-effective, investors are bullish on the stock market and, therefore, more inclined to buy stocks. Thus, the risk premium reflects a certain extent, the shift in market sentiment and investment preferences and can be seen as a benchmark for measuring investor sentiment.

(5) The exchange rate of the RMB against the USD. The spot price of WTI crude oil selected for the sample in US dollars. Foreign currencies are converted to RMB at the spot exchange rate on the same day to facilitate comparison and see its impact on domestic investment sentiment and the domestic new energy index.

All samples in this paper are selected to span the period from January 2019 to September 2022, as this period spans the years of normal, since the outbreak of the new crown epidemic and the outbreak of the Russia-Ukraine war trading situation, which better reflects the volatility of investor sentiment about the volatility of the study sample. Of these, 880 valid daily data were obtained after excluding trading days with no trading data.

As for the data sources, CSI Mainland New Energy Index and CSI 500 rolling P/E ratios were obtained from Choice Financial Terminal, while WTI crude oil spot price, RMB/USD exchange rate, and 10-year treasury yield were obtained from Investing Finance. （https://cn.investing.com/）

Table 1: Variable summary and symbol description.

Variables	Sample data	Symbols
New Energy Company Stock Price	CSI Mainland New Energy Index	NE_I
International crude oil prices	WTI Crude Oil Spot Price	WTI_P
P/E ratio	CSI 500 Rolling P/E Ratio	PE_{500}^{R}
Long-term interest rates	10-Year Treasury Yield	I_{10}^{R}
Exchange rates	RMB to US Dollar Exchange Rate	E_R
Risk premium	$\frac{1}{\text{CSI 500 Rolling P/E Ratio}} - 10 - \text{Year Treasury Yield}$	R_p

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3.2. Variable Description

Table 2: Variable statistics and description.

Variables	Average	Median	Maximum	Minimum	SD	Skewness	Kurtosis
NE_I	2581.121	2301.460	4805.060	1177.840	1168.252	0.304	-1.446
WTI_P	412.492	404.509	821.012	55.135	116.014	0.078	-0.058
PE_{500}^R	19.877	19.590	27.760	13.130	3.200	0.236	-0.637
I_{10}^R	3.01%	3.05%	3.44%	2.50%	0.21%	-0.226	-1.042
E_R	6.723	6.719	7.206	6.308	0.259	0.035	-1.403
R_p	2.15%	2.07%	4.78%	0.46%	0.96%	-0.463	-0.602

3.3. Unit Root Test

For each time series, the rootedness was first tested using the ADF unit root test, and the results are shown in Table 3. From the unit root test findings, it was obtained that the time series constituted by the raw data of CSI Mainland New Energy Index, WTI International Crude Oil Spot Price, CSI 500 Rolling P/E Ratio, Long-term Interest Rate, Exchange Rate, and Risk Premium was unstable.

Table 3: Unit root test table.

Variables	1% thresh-old	5% thresh-old	10% thresh-old	T-Value	P-Value	Conclu-sion	Differenc-ing
NE_I	-3.438	-2.865	-2.569	-1.112	0.710	Unstable	Stable
WTI_P	-3.438	-2.865	-2.569	-1.038	0.739	Unstable	Stable
PE_{500}^R	-3.438	-2.865	-2.569	-1.251	0.651	Unstable	Stable
I_{10}^R	-3.438	-2.865	-2.569	-1.463	0.552	Unstable	Stable
E_R	-3.438	-2.865	-2.569	-0.617	0.867	Unstable	Stable
R_p	-3.438	-2.865	-2.569	-0.759	0.831	Unstable	Stable

As shown in Table 4, this paper uses a combination of the Akira Pool Information Criterion (AIC), the Schwartz Criterion (SC), the Hanan and Quinn Criterion (HQ), and the Finite Prediction Error Criterion (FPE) to determine the lag order and obtain a lag order of 1 for the variables. The validation also further reveals that taking a first-order difference for all variables shows a stable conclusion at the 1% significance level.

Table 4: Lagging order selection table.

Lagging order	AIC	SC	HQ	FPE
0	13.682	13.698	13.688	874650.772
1	-0.978	-0.912*	-0.953*	0.376
2	-0.991*	-0.877	-0.947	0.371*
3	-0.98	-0.817	-0.918	0.375
4	-0.973	-0.761	-0.892	0.378

3.4. Johansen Co-integration Test

After the ADF unit root test, the variables presented a stable conclusion at the first-order difference. This paper wishes to explore further the relationship between the main variables, namely the CSI New Energy Index, the international crude oil price, and the risk premium. The use of the index of the Granger causality test is an ideal tool. However, the Granger causality test requires the original series to be stationary, and the actual data time series selected for this paper does not meet this requirement. However, if the time series are cointegrated, the conditions for the Granger causality test are also met.

The Johansen cointegration test can be judged using either the 'trace statistic' or the 'maximum characteristic root,' with the 'maximum characteristic root' as the final result in this paper if the absolute value of the trace The total value of the statistic is greater than the full value of the critical value, which implies significance. If there is a presented matter, the original hypothesis is rejected, and the lag order lags are set to lag order 1.

As can be seen from table 5, for hypothesis 'None (no cointegration)': its maximum eigenvalue value is 21.024, while the 1% critical value is 18.893, implying that the idea is rejected at the 10% level, i.e., no cointegration is possible; for hypotheses 'at most 1 cointegration ' or at most 2 cointegration', its maximum eigenvalue values are 3.286 and 1.061 respectively, as well as their absolute values, are lower than the total value of each critical value, implying acceptance of the hypothesis, which suggests that at least one long-run equilibrium relationship does exist between the three main variables.

Table 5: Johansen co-integration test table (Max-Eigenvalue).

Null Hypothesis	Eigenvalue	Max-Eigenvalue	10% threshold	5% threshold	1% threshold
None	0.024	21.024	18.893	21.131	25.865
Up to 1 co-integration	0.004	3.286	12.297	14.264	18.520
Up to 2 co-integration	0.001	1.061	2.705	3.841	6.635

3.5. Granger's Causality Test

Granger causality tests study the dynamic causality between indicators. They can be used to determine whether there is a causal relationship between economic variables and the direction in which they affect each other. In this paper, in the lag order selection of the Granger causality test, the lag order lags are chosen to order 1, at which point the value of AIC is minimized, and the output is optimal.

Before conducting the Granger causality test, first observe Diagram 1: the black dots in Diagram 1 are the inverse of the roots of the AR characteristic polynomial, and all lie within the unit circle, indicating that the model is stable and confirming that Granger causality tests can be done for the three variables in this paper.

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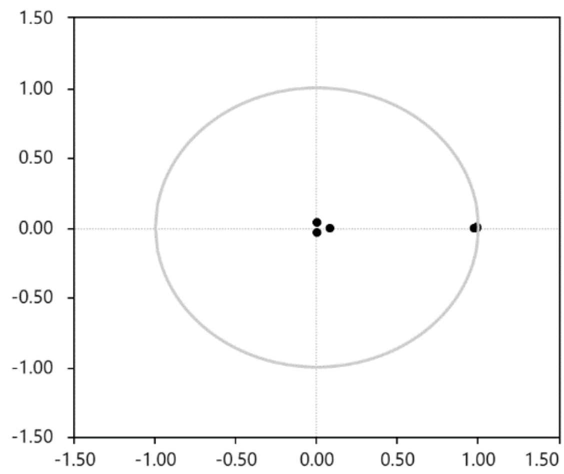

Figure 1: Inverse roots AR characteristic polynomial.

This paper's bound for the study probability is set at 0.05. Usually, a Probability less than 0.05 rejects the original hypothesis, which means that X_1 is the Granger cause of X_2； . In contrast, a Probability greater than 0.05 accepts the original hypothesis, which means that X_1 is not the Granger cause of X_2. As shown in Table 6, the domestic new energy index and global changes in crude oil prices can cause changes in risk premiums, but gl. Still, global oil prices to domestic new energy, domestic new energy index to international crude oil prices, and risk premiums to global crude oil prices and domestic new energy indexes cannot cause changes. In this paper, the bound for the study probability is set at 0.5; usually, a possibility less than 0.05 rejects the original hypothesis, which means that X_1 is the Granger cause of X_2； while a probability greater than 0.05 accepts the original hypothesis, which means that X_1, is not the Granger cause of X_2. As shown in Table 6, the domestic new energy index and international Changes in crude oil prices can cause changes in risk premiums. Still, global crude oil prices to domestic new energy, domestic new energy index to international crude oil prices, and risk premiums to global oil prices and domestic new energy indexes cannot cause changes.

Table 6: Granger's causality test table.

Null Hypothesis	F-value	Probability
NE_I does not Granger Cause WTI_P	2.877	0.090*
WTI_P does not Granger Cause NE_I	0.179	0.672
R_p does not Granger Cause WTI_P	0.003	0.955
WTI_P does not Granger Cause R_p	15.227	0.000**
R_p does not Granger Cause NE_I	0.003	0.954
NE_I does not Granger Cause R_p	8.393	0.004**

3.6. Impulse Response

The impulse response diagram shows the dynamic impact of a shock to a variable on the variable itself or other variables; if it is greater than 0, then it is a positive shock, conversely less than 0, then it is a negative shock, the larger the absolute value means the larger the shock, the closer the value to 0 means the smaller the shock.

We have obtained that the domestic new energy index is the cause of the fluctuation of the risk premium, and the international crude oil price is also the cause of the change of the risk premium.

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Therefore, further impulse response analysis was conducted to study the lags of the impact of the domestic new energy index and the international crude oil price on the risk premium. The results are shown in Diagram 2.

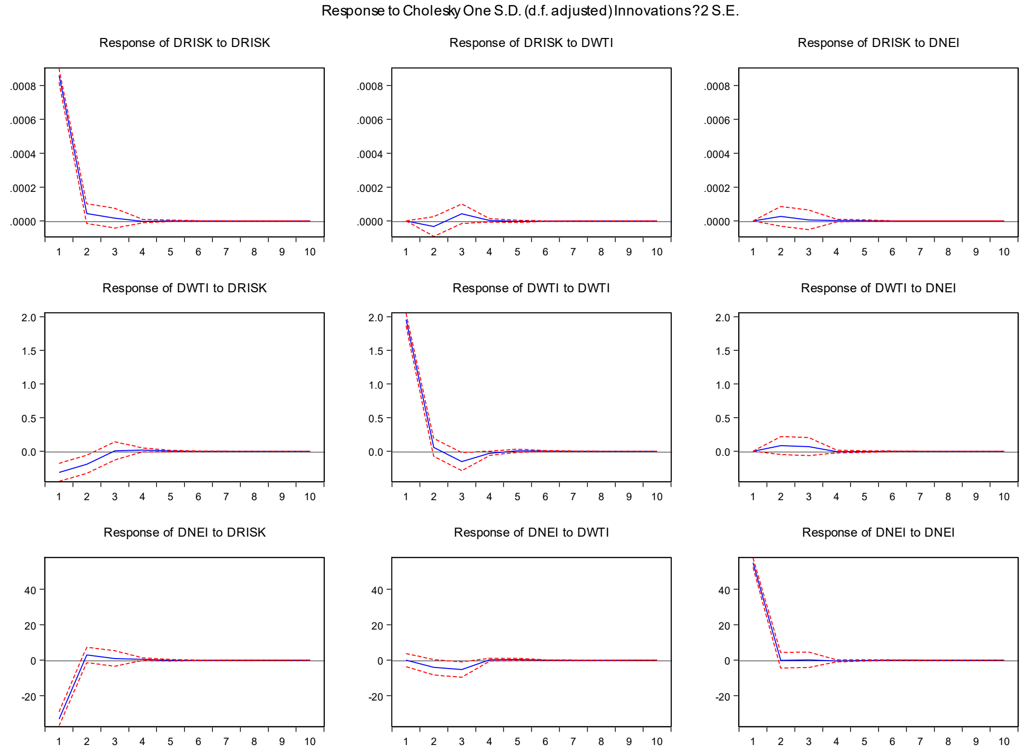

Figure 2: Impulse response diagrams of $\boldsymbol{NE_I}$、 $\boldsymbol{WTI_P}$ and $\boldsymbol{R_p}$.

As shown in Diagram 2, when describing the impulse response, the focus is on the short-term response, the Response of B to A, i.e., one standard deviation unit of A to B, where the solid blue line is the change in B and the red dashed line is the two times normal deviation interval. As the original data series is non-stationary, the time series returns to a stationary state after making a first-order difference.

The impact of international crude oil price on risk premium is insignificant, with negative implications in the first 2 periods and positive effects in periods 3~4; the impact of the new energy share price on risk premium is also negligible, with positive impact in the first 3 periods; the result of risk premium on international crude oil is negative in the first 2~2.5 periods; the effect of the new energy share price on global crude oil price is positive in the first 3 periods; the impact of risk premium on new energy share price is very The impact of the risk premium on the share price of new energy is very significant, with a negative effect on the first 1~1.5 periods and then rapidly turning positive; the impact of the international crude oil price on the share price of new energy companies is significantly positive in the first 3 periods; development of the risk premium and the impact of the new energy share price on itself are both positive, the former is small, and the latter is significant. The impact of international crude oil price on itself is a small positive impact in the first 1 to 1.5 periods, then a small negative effect. However, all shocks are short-term, which is also determined by the characteristics of financial markets.

3.7. Variance Decomposition

Variance decomposition is the process of decomposing the variance of the forecast error of each exogenous variable in the model into components that are correlated with each endogenous variable according to their causes, i.e., analyzing the contribution of each shock to the change in the endogenous variable, to understand the relative importance of each shock to the endogenous variables of the model. The critical variable chosen for this paper is the risk premium for the variance decomposition, and the results obtained are shown in Table 7.

Table 7: Variance decomposition plot of the risk premium(R_p).

Period	S.E.	WTI_P(%)	NE_I(%)	R_p(%)
1	0.001	2.151	26.024	71.825
2	0.001	2.693	25.035	72.272
3	0.001	2.754	24.705	72.541
4	0.002	2.669	24.512	72.819
5	0.002	2.534	24.366	73.1
6	0.002	2.382	24.24	73.378
7	0.002	2.228	24.124	73.648
8	0.002	2.077	24.012	73.911
9	0.002	1.935	23.9	74.164
10	0.003	1.803	23.789	74.408
11	0.003	1.684	23.675	74.642
12	0.003	1.577	23.559	74.864
13	0.003	1.484	23.44	75.076
14	0.003	1.405	23.318	75.277
15	0.003	1.341	23.193	75.466

The period is the number of periods of variance decomposition, i.e., the forecast period of risk premium, S.E. represents the standard deviation of risk premium volatility forecast, WTI_P and NE_I are the percentages of the forecast variance of risk premium volatility that are perturbed by international crude oil price and CSI New Energy Index, and R_p is the percentage of its perturbation, the sum of the three columns is 100%. The table shows that in the first period, 71.82% of the risk premium movement is due to itself, 26.02% is due to the new energy movement, and 2.15% is due to the international crude oil price movement. Over time, there was a slight increase in the proportion of own disturbances in risk premium movements and a slight decrease in the other two, which remained stable at approximately 76%, 23,% and 1% [2].

4. Conclusion and Forecast

The above empirical tests yield that in the short run, the shocks to new energy share prices from international crude oil prices and risk premiums are significant, with the former wonders consistently having significant short-run positive effects while the latter shifts from significant short-run negative effects to significant short-run positive results, which is in line with the findings of unidirectional short-run causality between oil prices and share prices of alternative energy companies obtained by Ripsy Bondia (2016). The shocks to risk premia are less pronounced for international crude oil and new energy share prices, with the former surprises turning from a short-term insignificant negative impact to a short-term negligible positive impact. At the same time, the latter has been a short-term little positive impact. Shocks to international crude oil prices are also insignificant for new energy share prices and risk premia, with the shocks being short-run insignificantly positive and the latter being short-run significant and negative.

However, in the long run, international crude oil prices do not influence new energy share prices, which is contrary to the empirical findings of Qing Zeng [10] that global crude oil prices have a significant impact on the share prices of new energy companies, which can also reflect the fact that the new energy stock market in China has shown a high degree of independence in recent years. The fact that international crude oil can have an impact on the risk premium but not vice versa, as well as the fact that fluctuations in new energy share prices do not cause changes in international crude oil prices, suggests that China's financial trading market is still unilaterally closed, i.e., global financial derivatives price movements can most likely affect domestic derivatives financial market trading, but domestic does not affect international. In addition, trends in new energy stock prices can influence changes in risk premiums but not vice versa, suggesting an active-passive relationship in the new energy stock trading market, i.e., as the new energy sector grows, investor sentiment is high and will continue to be bullish on new energy stocks. But new energy stocks do not continue to rise or fall because of the high level of investor sentiment. The change in investor sentiment is caused by itself at 71.82%, by the shift in ne stock prices at 26.02%, and by the new energy change in global crude oil prices at 2.15%, indicating that most investors remain focused on the domestic financial trading market.

In conclusion, both the development over time and the choice of the key variables' will influence the final conclusions. The risk premium selected in this paper is only a proxy for investor sentiment and thus leads to similar or opposite conclusions to the previous empirical results i.e., the research methodology proposed in this paper for risk premium may not be the best tool to study the correlation between investor sentiment, international crude oil prices and new energy share prices. Still, both have some validity, which is subject to further research.

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