Research on volatility spillover effects between traditional energy market and China's new energy vehicle stock market

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Abstract. Due to the issues of energy security and climate change, many countries have deeply adjusted the energy structure for the sustainable development of the national economy. With the increase of uncertainty in the energy market in recent years, China's new energy vehicle industry has developed rapidly, and the price fluctuation of new energy vehicle industry is closely related to that of traditional fossil energy. Therefore, we use the TVP-VAR-DY model to analyze the time-varying volatility spillover effect between the international crude oil futures market and China's new energy vehicle stock market. The results show that the volatility spillover effect between the international crude oil futures market and China's new energy vehicle market has obvious time-varying characteristics. The international crude oil market is the net exporter in the system, while China's new energy vehicle market is the main net recipient in the system. The sensitivity of directional spillover effect in extreme risks of different markets to different extreme events is quite different. Finally, the conclusions of this paper provide reference for investors and put forward corresponding suggestions for the development of new energy vehicle industry.

Keywords: Crude oil, New energy vehicle, Volatility spillover effect, TVP-VAR-DY model.

1. Introduction

With the integration of the global economy, different financial markets have been increasingly connected. External shocks to one market can spread to other markets through various channels. International commodities are both strategic resources and investment assets. Many studies show that crude oil is the most important commodity, and its price fluctuation is related to the stable development of the real economy and financial market. In recent years, the sharp fluctuation of oil prices has brought great uncertainty to the development of the global economy. The price of crude oil is affected by a variety of factors, such as market supply and demand, the exchange rate of the US dollar, technological innovation, speculative factors and so on. In recent years, with the rapid development of the world economy, due to the rapid consumption of fossil energy, the ecological environment is gradually deteriorating, energy security and climate change issues have become the focus of attention of all countries in the world, especially the greenhouse effect, various extreme weather and other environmental problems, seriously threatening the sustainable development of human society. In order to meet the rapidly growing demand for energy while addressing environmental concerns, the new energy industry has developed rapidly due to its availability and environmental friendliness.

Since the implementation of the Renewable Energy Law, China's hydropower, solar photovoltaic, wind and other power generation capacity ranks first in the world, laying the foundation for a comprehensive transformation of the energy structure. As the world's largest energy consumer and carbon emitter, the report of the 20th National Congress of the Communist Party of China clearly points out that it actively and steadily promotes carbon peak and carbon neutrality to ensure energy security. At the same time, it emphasized the necessity to promote the development of strategic emerging industry integration clusters, and build a number of new growth engines including new energy and green environmental protection. At present, developing countries are faced with a series of arduous tasks such as improving people's livelihood, eradicating poverty, controlling pollution and so on.

The majority of research findings agree that the development of renewable energy sources such as solar, wind and hydropower is crucial to combating climate change and conducive to sustainable development of agriculture, industry and urbanization. Similarly, the replacement of fossil fuels by nuclear power has played a key role in the carbon peak. Energy technology innovation is another important way to achieve energy conservation and emission reduction, transforming the coal-based energy consumption structure, establishing a stable energy supply security system, and developing modern industry are particularly important for controlling carbon emissions. The development of new energy has become the fundamental way to solve the contradiction between environmental pollution and energy consumption growth.

After decades of rapid development, the automobile industry has become one of the pillar industries in China. Especially in recent years, China's automobile production and sales have ranked first in the world. However, the development of conventional vehicles is dependent on oil and has led to serious environmental problems. The urgent need of energy security and environmental protection has prompted all countries to develop the new energy vehicle industry from a forward-looking and strategic perspective. As one of the strategic emerging industries, the new energy vehicle industry has become an important breakthrough in China's energy conservation and emission reduction, economic revitalization and industrial structure transformation. According to the data released by the China Association of Automobile Manufacturers, in May 2021, domestic sales of new energy vehicle in China reached 217,000, an increase of 159.7%. From January to May 2021, the cumulative sales reached 950,000 units, an increase of 224.2%. According to the latest forecast of the China Association of Automobile Manufacturers, the annual sales of new energy vehicle are expected to exceed 2 million in 2021, reaching 2.4 million, and the domestic new energy vehicle market is expected to grow by 46%. With China already committed to achieving carbon peak by 2030 and carbon neutral by 2060, the internal and external environment of the new energy vehicle market is constantly being optimized. The "New Energy Vehicle Industry Development Plan (2021-2035)" adopted in October 2020 has laid a solid foundation for the development of China's new energy automobile industry in the next 15 years. At the same time, local governments have introduced policies to encourage the consumption of new energy vehicles. The policy system of the national and local governments has gradually improved, providing strong support for the development of the new energy vehicle industry.

With the intensification of financial integration and liberalization, the risk transmission effect between different industries is significantly enhanced. Therefore, exploring the risk spillover effect between the traditional energy market and the new energy vehicle market and revealing its internal mechanism and law is of great practical significance to help investors, risk managers and policy makers effectively prevent carbon financial risks, promote the healthy and stable operation of the carbon market and realize the goal of "double carbon".

2. Literature review

2.1. Subsection

The research on the volatility spillover effect between crude oil market and the overall stock market has always been one of the hot spots in the financial academic circle. The foreign academic circle has a long history of studying the correlation between energy market price and stock market price, especially the research literature on the relationship between crude oil market price and stock market price. In early studies, many scholars believed that there was no obvious correlation between crude oil and stocks. Capsimalis and Chen (1986) used multi-factor regression to compare the impact of crude oil price and other macro factors on stock returns respectively, and the results showed that there was no significant relationship between crude oil and stock prices. Huang and Stoll (1996) also supported Chen's conclusion based on the results of VAR model. They selected crude oil futures and stocks as research objects, and used vector autoregressive model to study the relationship between them, and came to the conclusion that there was no obvious relationship between them. They believe that although the yield of crude oil futures will not affect the stock market yield, but it will have a certain impact on the yield of oil companies. Hamilton (2003) proposed that both oil price and stock price are intrinsically related to economy, and there is solid evidence in literature to prove the close relationship between oil price and economy. Basher and Sadorsky (2006) selected 21 emerging markets such as Brazil and crude oil futures as research objects through the international multi-factor model, and conducted an empirical analysis of their relationship. The empirical results show that the β coefficient of oil price plays an important role in the relevant return rate of these emerging stock markets. Park and Ratti (2008) selected the stock markets of 13 countries in the United States and Europe, analyzed the impact of oil price fluctuations on them, and found that there was a significant negative correlation between the fluctuations of international crude oil prices and the returns of each stock market. Elder and Serletis (2010) points out that the effects of crude oil prices will filter through the sectoral boundaries that affect a range of economic activities through inflationary pressures and production costs. Bastianin (2016) explored the relationship between crude oil and stock market from the perspective of demand and supply, and took the relevant data of the "Group of Seven" member countries as samples. The results showed that crude oil on demand side would have an impact on stocks, but crude oil on supply side would not have a fluctuation impact on stocks. Zhang.ect, (2017) adopted the method of measuring connectivity proposed by Diebold and Yilmaz (2009, 2012, 2014) to study the relationship between oil shocks and returns in six major global stock markets, and their paper proposed that the contribution of oil shocks to the world financial system is limited. However, changes in oil prices can be explained by information from the financial system. In addition, they also found that oil shocks can sometimes have a significant impact on the stock market and proved that only big shocks are very important for the stock market by using rolling window analysis. Bagchi (2017) mainly studied the impact of crude oil price fluctuations on the stock markets of the BRIC countries, and found that the volatility of crude oil prices has an asymmetric effect on the stock markets of the four countries. Wang Qizhen and Wang Yudong (2018) studied the bidirectional relationship between the volatility of international crude oil prices and the volatility of Chinese stock market, and found that the volatility between international oil prices and Chinese stock market is bidirectional and asymmetric, and the spillover effect of crude oil price volatility is more obvious. Kang Jijun et al. (2021) analyzed the price transmission mechanism between energy and the stock market, and constructed the Divisia energy price index reflecting several major energy consumption in China. The research showed that the total demand of the global economy and the specific demand of the energy market had a great negative impact on the price of industrial stocks in China and this impact on the industrial chain in the middle and downstream enterprises are inconsistent.

3. Methodology

This paper uses the research method of Antonakakis et al. (2020) for reference to explore the volatility spillover effect between the international crude oil futures market and China's new energy vehicle stock market. In order to overcome the defects of the traditional DY spillover index model, we combined the time-varying parameter vector autoregressive TVP-VAR model with DY spillover index method based on generalized variance decomposition to construct a time-varying parameter vector autoregressive spillover index model for empirical research. Compared with the traditional DY model, this model has three main advantages: Firstly, the Time-varying-variance-Covariance structure can capture the common differential process of financial series, which makes the TVP-VAR model perform better than the traditional VAR model, and is conducive to producing regression results that are more in line with the economic reality. Secondly, when calculating the dynamic spillover index, because it does not involve scrolling window analysis, it is not necessary to set the rolling window size arbitrarily and effectively avoid the loss of observed values. Thirdly, robust estimation based on Kalman filter reduces the sensitivity to outliers.

Specifically, the construction process of the TVP-VAR-DY model is as follows:

Take TVP-VAR (1) as an example. Firstly, define a first-order TVP-VAR model:

$$y_t = \beta_t y_{t-1} + \varepsilon_t \;\; \varepsilon_t|\Omega_{t-1} \sim N(0, \sum_t) \tag{1}$$

$$y_t = y_{t-1} + v_t \;\; v_t|\Omega_{t-1} \sim N(0, R_t) \tag{2}$$

The y_t, y_{t-1} and ε_t are N×1 dimensional vectors, β_t and $\sum_t$ are N×N dimensional matrices, parameter y_t and v_t are $N^2 \times 1$ dimensional vectors, R_t is $N^2 \times N^2$ dimensional matrix.

In order to calculate the GIRF and GFEVD, we transform the TVP-VAR to its vector moving average (VMA) representation based on the Wold representation theorem. Retrieving the VMA representation can be illustrated byrecursive substitution:

$$y_t = \sum_{j=0}^{\infty} B_{jt}\, \varepsilon_{t-j} \tag{3}$$

The time-varying coefficient B_t matrix of the TVP-VMA model was extracted to calculate the generalized forecast error variance decomposition (GFEVD). In the process of generalized forecast error variance decomposition, $\tilde{\varphi}_{ij,t}^{g}(H)$ is defined as the normalized directional spillover effect of j to i, which can be expressed as:

$$\tilde{\varphi}_{ij,t}(H) = \frac{\sum_{t=1}^{H-1} \psi_{ij,t}^2}{\sum_{j=1}^{m} \sum_{t=1}^{H-1} \psi_{ij,t}^2} \tag{4}$$

When the $\sum_{j=1}^{m} \tilde{\varphi}_{ij,t}(H)$=1 and $\sum_{i,j=1}^{m} \tilde{\varphi}_{ij,t}(H) = m$, the denominator represents the cumulative effect of all shocks, while the molecular represents the cumulative effect of shocks in the variable i. We construct the total connectivity index by the following formula by using GFEVD:

$$C_t(H) = \frac{\sum_{i,j=1, i\neq j}^{m} \tilde{\varphi}_{ij,t}(H)}{\sum_{i,j=1}^{m} \tilde{\varphi}_{ij,t}(H)} * 100 = \frac{\sum_{i,j=1, i\neq j}^{m} \tilde{\varphi}_{ij,t}(H)}{m} * 100 \tag{5}$$

This connectivity approach shows how shocks from one variable spill over into other variables. First, we refer TO the case where the shock of variable i is passed on to all other variables j as the overall directivity spillover index (TO) to the other variables and define it as:

$$C_{i\rightarrow j,t}(H) = \frac{\sum_{j=1, i\neq j}^{m} \tilde{\varphi}_{ji,t}(H)}{\sum_{j=1}^{m} \tilde{\varphi}_{ji,t}(H)} * 100 \tag{6}$$

Second, we calculate the directional connectivity that variable i receives FROM variable j, called the total directional spillover index (FROM) to which other variables are subjected, defined as:

$$C_{i\leftarrow j,t}(H) = \frac{\sum_{i=1, i\neq j}^{m} \tilde{\varphi}_{ij,t}(H)}{\sum_{i=1}^{m} \tilde{\varphi}_{ij,t}(H)} * 100 \tag{7}$$

Then we subtract the total directional spillover index for the other variables from the total directional spillover index for the other variables to get the NET total spillover index (NET), which can be interpreted as the net spillover effect of variable i on the analyzed network system. If the net directional spillover index of variable i is positive (negative), it means that the influence of variable i on the system is greater (less) than that of the system to which it is affected:

$$C_{i,t} = C_{i\rightarrow j,t}(H) \text{-} C_{i\leftarrow j,t}(H) \tag{8}$$

Finally, we further decompose the net total spillover index to obtain the spillover index between two variables, which can be expressed as:

$$NPDC_{ij}(H) = \left(\tilde{\varphi}_{jit}(H) - \tilde{\varphi}_{ijt}(H)\right) * 100 \tag{9}$$

It represents the net spillover effect of variable i on variable j. If $NPDC_{ij}(H) > 0 (NPDC_{ij}(H) < 0)$, means that the influence of variable i on variable j is greater than (less than) that of variable j.

4. Data

4.1. Data sources

In this paper, four representative proxy variables in the international crude oil market and China's new energy vehicle market are selected by referring to recent relevant literature studies and combined with the availability of data. For the international crude oil market, daily price data of WTI crude oil futures and Brent crude oil futures are selected as proxy variables. For China's new energy vehicle market, the daily closing prices of CSI New Energy Vehicle Index and CNI New Energy Vehicle Index are selected as their proxy variables.

Based on the availability of data, the sample period adopted by daily degree data of this paper is set as May 20, 2015 to January 9, 2024 and the data come from EIA and Choice financial terminals. In order to avoid the influence of heteroscedasticity, logarithmic rate of return is processed for each variable in this paper, and 8348 observed values are finally obtained. It is expressed by WTIF, BRENTF, CSINEV and CNINEV respectively, where the formula of logarithmic return is:

$$R_{it} = 100 \times (lnp_{it} - lnp_{it-1}) \tag{10}$$

4.2. Descriptive statistic

错误!未找到引用源。**.** Descriptive statistics of the returns.

	WTIF	BRENTF	CSINEV	CNINEV
Mean	0.011	0.009	0.001	-0.004
Max	31.963	19.077	7.906	7.716
Min	-60.168	-37.340	-9.715	-9.730
Std.Dev	3.365	2.731	2.173	2.140
Skewness	-2.611	-1.615	-0.287	-0.406
Kurtosis	67.323	28.477	4.910	5.148
Jarque-Bera	3632157.541^{***}	57349.639^{***}	345.896^{***}	458.557^{***}
ADF	-47.788^{***}	-45.900^{***}	-43.483^{***}	-43.172^{***}

Note: *, **, and *** indicate significance at the 10%, 5% and 1% levels respectively.

As shown in Table 1, we conducted descriptive statistics on these four rate of return series. As can be seen from Table 1, among all the returns, WTIF has the highest average return rate, followed by BRENTF, CSINEV and CNINEV have the lowest average return rate. Meanwhile, the volatility of the international crude oil market is also higher than that of China's new energy vehicle market during the sample period. This indicates that the WTIF market, which has the highest volatility, is the most risky market, while the new energy vehicle market has less risk. According to the results of skewness, kurtosis and Jarque-Bera, all return series are negative skewness and present the form of "peak and thick tail distribution", which does not meet the normal distribution. The ADF test shows that all four return series are stable at 1% significance level.

5. Empirical results

5.1. Analysis of static volatility spillover

错误!未找到引用源。**.** Volatility spillovers index (%) table from variable (j) to variable (i)

	WTIF	BRENTF	CSINEV	CNINEV	FROM
WTIF	52.1	44.9	1.5	1.5	47.9
BRENTF	44.6	51.9	1.7	1.8	48.1
CSINEV	1.7	2.0	49.0	47.3	51.0
CNINEV	1.9	2.2	47.1	48.8	51.2
TO	48.3	49.0	50.3	50.6	Total:

NET	0.3	0.9	-0.7	-0.6	49.6%

First, we use the constant coefficient VAR model and DY framework to calculate the full sample volatility spillover. Based on AIC information criterion, we set the optimal lag order of VAR model to 4, and the volatility error variance prediction period of generalized variance decomposition to 10 days. Table 2 shows the static matrix of the volatility spillover index of the international crude oil market and China's new energy vehicle stock market. "Total" represents the total volatility spillover and the main diagonal of the matrix represents the market's impact on its own volatility. "TO" represents the total spillover to other markets, "FROM" represents the total spillover from other markets and "NET" represents the net spillover index, where negative values are net recipients and positive values are net exporters.

As can be seen from the results of Table 2, the total volatility spillover index is as high as 49.6%, that is, indicating that the international crude oil market and China's new energy vehicle stock market have a high risk correlation. Among them, the spillover effect of CNINEV index to other markets is larger, and the spillover index of conduction is higher which is reaching 50.6%, followed by CSINEV index, reaching 50.3%. In addition, the two indexes also received the highest volatility spillovers from other markets, with CNINEV at 51.2% and CSINEV at 51.0%. From the perspective of net spillover indicators, the international crude oil market is a net exporter, while China's new energy vehicle market is a net recipient. The maximum contribution of BRENTF to spillover of other factors is 0.9%, and the maximum influence of CSINEV to spillover of other factors is -0.7%.

5.2. Total dynamic volatility spillover

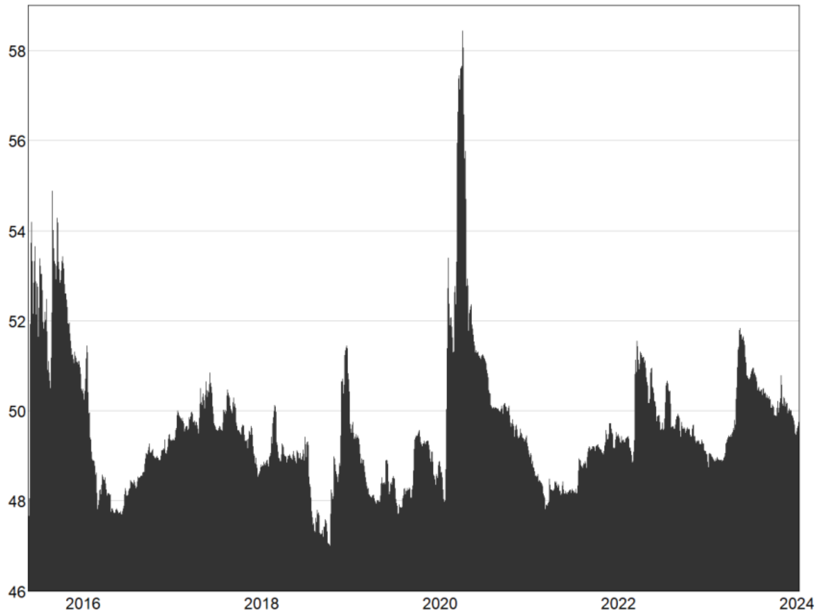

Fig. 1 Total dynamic volatility spillover index (%) of four asset classes

The static spillover index does not reflect the time-varying characteristics of the relationship between markets. Therefore, dynamic indicators should be observed to further study the event characteristics of inter-market relations. Fig.1 shows the time-varying characteristic curve of the total volatility spillover effect of the four markets during the whole sample period. It can be seen from the figure that the total spillover effect during the sample period changes sharply over time, ranging from 46% to 59%, and the total spillover effect will change significantly when extreme events occur. This suggests that volatility spillovers are very sensitive to extreme events. Since the end of quantitative easing in November 2014, the global market oversupply, the US dollar continued to strengthen, oil prices plummeted, down about 30% in 2015. At the same time, the Shanghai Composite Index dropped from more than 5000 points to 3700 points, the stock market fluctuated violently in June 2015. At the end of 2015, the impact brought by the Fed's interest rate hike boots has further increased the uncertainty of the international economic and financial order. With the decline of energy prices and the collapse of China's overall stock market, the related markets have suffered a greater impact, resulting in a sharp increase in the inter-market spillover effect index to 55% in 2016. Since the second half of 2018, credit defaults in the bond market have been frequent, Sino-US trade frictions have escalated, and the total spillover effect has continued to rise at the end of 2018. The outbreak of the global COVID-19 epidemic in 2020 made the spillover index of the international crude oil market and China's new energy vehicle market rise significantly, and the total spillover effect reached a peak of about 58.5%, and gradually stabilized in the following period of time.

It can be seen that the international crude oil futures market and China's new energy vehicle stock market have frequent information transmission and the demand-side shock and supply-side shock of the energy and economic market may be related. When major energy economy-related events occur, volatility in global markets will exacerbate spillovers between markets to some extent.

5.3. Directional volatility spillover

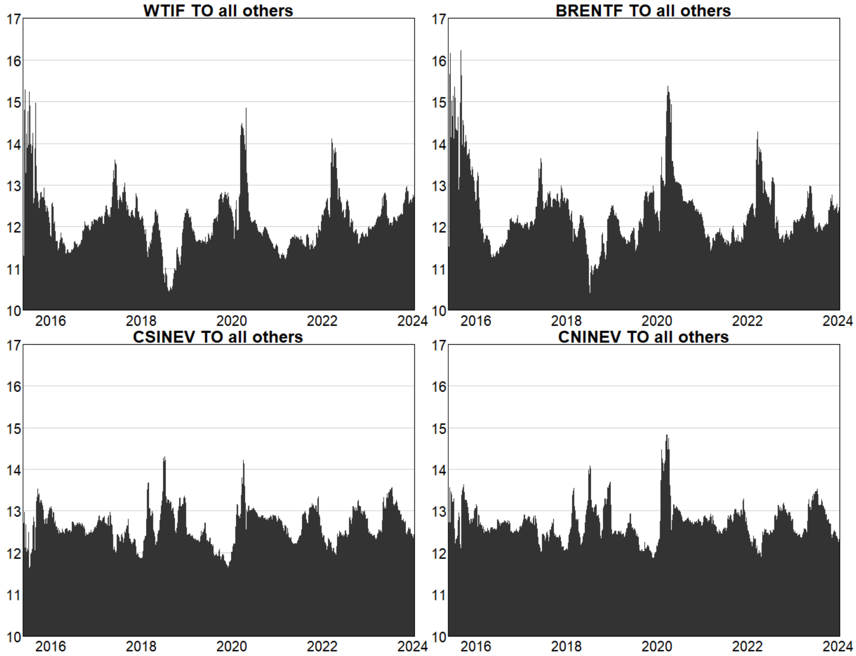

Fig. 2 Directional volatility spillovers, FROM four asset classes

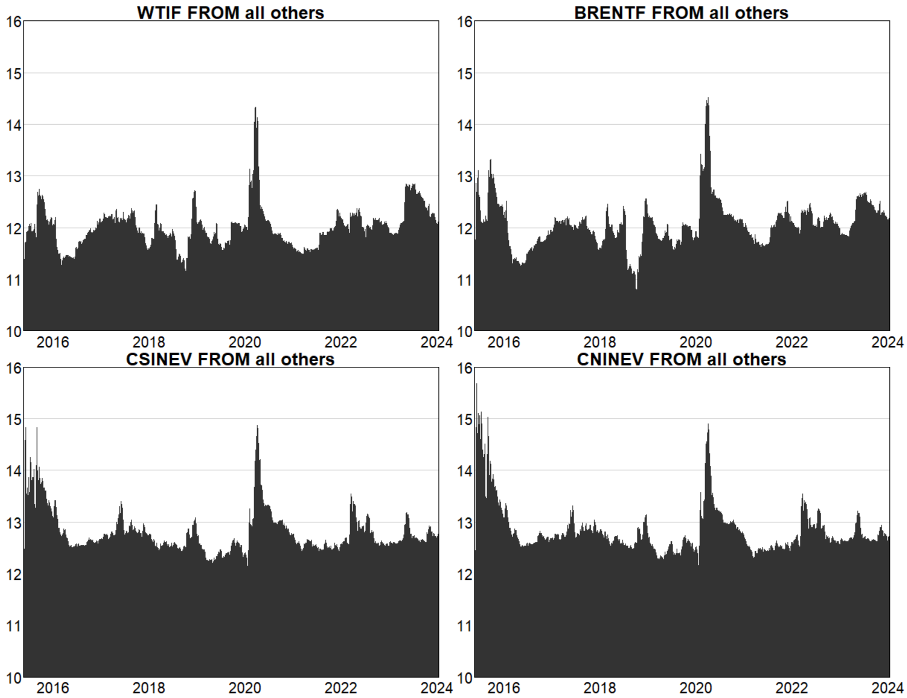

Fig. 3 Directional volatility spillovers, TO four asset classes

Figure 2 and Figure 3 show the timing characteristics of the total spillover effect (TO) and the directional spillover effect (FROM) of a market extreme risk respectively. As can be seen from Figure 2, both markets have large fluctuations under extreme events at the same time point, but the degree of volatility spillover (TO) and the reasons for volatility are quite different between the international crude oil futures market and China's new energy vehicle stock market. First of all, the total (TO) level of the international crude oil market is slightly lower than that of China's new energy vehicle market, but the total spillover effect (TO) of the international crude oil market is more volatile. Secondly, the total spillover effect (TO) of different market extreme risks has different sensitivity to extreme events. Among them, the total spillover effect (TO) of the international crude oil market rose sharply when the international oil price plummeted in 2015 and the major economic events of the Federal Reserve's interest rate hike landed at the end of 2015, while China's new energy vehicle market was relatively stable during this period. The spillover effect (TO) of the international crude oil market fluctuates significantly after the outbreak of the COVID-19 epidemic and the conflict between Russia and Ukraine, while the spillover effect (TO) of China's new energy vehicle market is only sensitive to the impact of the COVID-19 epidemic outbreak. As can be seen from Figure 3, the total spillover effect (FROM) level of the international crude oil market is lower than that of China's new energy vehicle market, but the total spillover effect (FROM) of the international crude oil market is more volatile. Different from the spillover effect (TO), the spillover effect of the international crude oil market did not fluctuate significantly during the two major economic events of the oil price crash and the Federal Reserve's interest rate hike in 2015, while the spillover effect (FROM) of China's new energy vehicle market fluctuated sharply during this period.In addition, in 2020, the new coronavirus epidemic is spreading rapidly around the world, the breakdown of the OPEC+ meeting negotiations has caused the world's crude oil prices to plummet, and the Bank of China's "crude oil treasure" explosion event in 2020 has added a new round of volatility to China's stock market, resulting in a significant volatility spillover effect (FROM) of the two markets.

5.4. Net volatility spillover

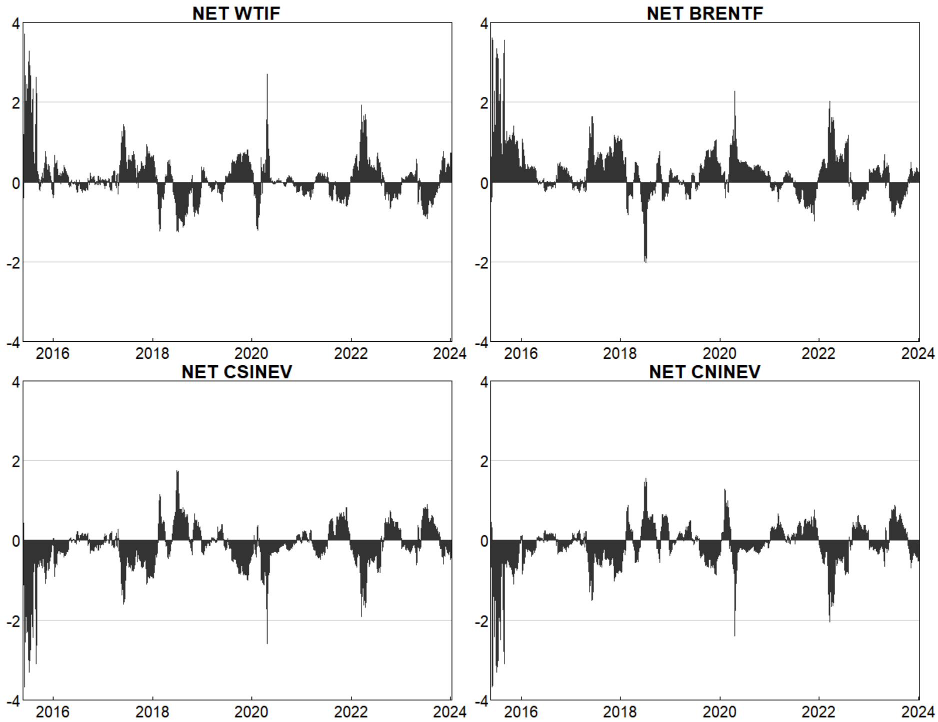

Fig. 4 Net volatility spillovers of four asset classes

Figure 4 shows the time-varying characteristics of the net directional spillover effect of the four markets over the entire sample period after the spillover effect (TO) and spillover effect (FROM) offset each other. As can be seen from Figure 4, during the whole sample period, the fluctuation trend of the net spillover effect of the international crude oil market and China's new energy vehicle stock market showed a symmetrical feature. The net spillover index of the international crude oil market was mostly positive, while that of China's new energy vehicle stock market was mostly negative. The net spillover effect of Brent crude oil futures market is stronger than that of WTI crude oil futures market, and the international crude oil market has been in the position of exporter in the risk transmission for a long time. China's new energy vehicle market generally shows a net spillover effect (FROM) , playing the role of receiver in the risk transmission, and absorbing the risks of various energy markets and stock markets. The net directional spillover effect of the four markets show an alternating trend of positive and negative fluctuations, which reflects the diversity of the spillover effects of the energy market and the stock market over time.

5.5. Pairwise volatility spillover

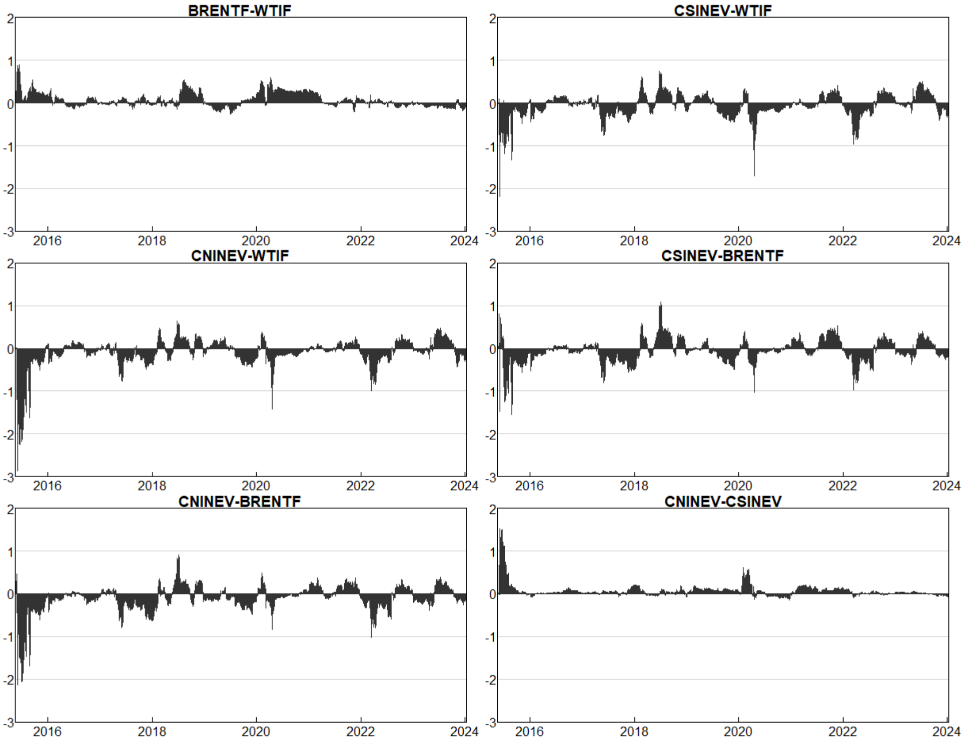

Fig. 5 Net pairwise volatility spillovers

As shown in Figure 5, by further studying the dynamic net spillover effect between each energy market and the stock market, the difference characteristics of the volatility spillover index between each market and the specific volatility spillover direction between the two markets are clarified. It can be seen that the international crude oil futures market shows its position as a net exporter of volatility spillover to China's new energy vehicle stock market before 2019, while the new energy vehicle market is a risk recipient. The continued low international oil prices in 2015 exacerbated the turmoil in the energy market, and also passed on to the new energy vehicle stock market, which intensified the net volatility spillover effect between the two markets. With the frequent occurrence of credit defaults in the bond market in the second half of 2018, the escalation of Sino-US trade friction, the two markets have alternately been in the position of net spillovers, and China has significantly increased its oil reserves since it became the world's largest importer of crude oil in 2015, and China's oil supply and demand have gradually moved toward balance, making China's stock market greatly reduced by the impact of oil shocks.

Finally, by observing the net volatility spillover effect between similar markets, it can be seen that the BRENTF market in the international crude oil futures market has a stronger spillover effect, and the CNINEV market in China's new energy vehicle stock market has a stronger spillover effect. The

BRENTF market and CNINEV market have a greater impact on WTIF market and CSINEV market respectively.

6. Conclusion

Based on the daily data from May 20, 2015 to January 9, 2024, this paper conducts TVP-VAR-DY model to obtain a series of spillover indexes, and studies the volatility spillover effect between the international crude oil futures market and China's new energy vehicle stock market from the static and dynamic perspectives respectively. The empirical analysis results show that: Firstly, the volatility of the international crude oil futures market and China's new energy vehicle stock market has a significant cross-market spillover effect. At the same time, the volatility spillover effect between different markets is closely related to the domestic and international economic situation and financial market environment and has obvious time-varying characteristics. Secondly, from the perspective of static spillover effect, the international crude oil market has a high risk correlation with China's new energy vehicle stock market, and CNINEV index has the largest spillover effect on other markets and other markets it is subject to. From the perspective of net spillover index, the international crude oil market is a net exporter, while China's new energy vehicle stock market is a net recipient. Thirdly, from the perspective of dynamic spillover effect, the volatility spillover index is very sensitive to extreme economic events. Under the impact of extreme events, the volatility spillover index of traditional energy market and new energy vehicle stock market rises significantly. Finally, the analysis results of directional spillover effect and net pairwise spillover effect show that the directional spillover and spillover index of each market change constantly with the economic and financial environment and the international crude oil futures market has a significant net spillover effect on China's new energy vehicle stock market.

Based on the above research conclusions, this paper puts forward the following policy recommendations: First of all, for investors, the close correlation between energy prices and stock prices may reduce the diversification effect of the portfolio, and then affect the return of the portfolio, especially holding a portfolio of energy and stocks will face greater risks in the short term in times of financial turmoil. Therefore, investors should attach great importance to the volatility spillover risk between the two types of markets, regard the spillover effect as an important factor affecting portfolio returns and do a good job in portfolio risk management. Secondly, for policy makers, it is necessary for the regulatory authorities to introduce corresponding regulatory and institutional rules, improve the pricing mechanism of the stock and commodity markets, and reduce the herding behavior between the two, so as to reduce the volatility spillover effect in financial markets and prevent excessive volatility of energy prices and stock prices. Especially during extreme economic events, government departments should take necessary unconventional policy measures, such as increasing market transaction costs, guiding investors' asset price expectations and so on to reduce the impact of spillover effects and prevent systemic financial risks.

References

[1] Ahmad, W., On the dynamic dependence and investment performance of crude oil and clean energy stocks[J]. Research in International Business and Finance, 2017, 42:376-389.

[2] Basher. S.A. Sadorsky. P. Oil Price Risk and Emerging Stock Markets[J], Global FianceJournal, 2006, 17(2) :224-251.

[3] Bagchi, B., Volatility spillovers between crude oil price and stock markets: evidence from BRIC countries[J]. International Journal of Emerging Markets, 2017, 12(2):352-365.

[4] Bastianin, A., Conti, F., Manera, M., The impacts of oil price shocks on stock market volatility: evidence from the G7 countries[J]. Energy Policy, 2016, 98:160-169.

[5] Capsimalis,G. P,Chen,et al. Electrodeposition and characterization of niobium from fused-fluoride electrolytes. Final technical report[J]. 1986.

[6] Corbet S, Goodell J W, Günay S. Co-movements and Spillovers of Oil and Renewable Firms under Extreme Conditions: New Evidence from Negative WTI Prices during COVID-19[J]. Energy Economics, 2020, 92: 104978.

[7] Diebold F X, Yilmaz K. Measuring financial asset return and volatility spillovers, with application to global equity markets[J]. The Economic Journal, 2009, 119(534): 158-171.

[8] Diebold F X, Yilmaz K. Better to give than to receive: Predictive directional measurement of volatility spillovers[J]. International Journal of forecasting, 2012, 28(1): 57-66.

[9] Diebold F X, Yilmaz K. On the network topology of variance decompositions: Measuring the connectedness of financial firms[J]. Journal of econometrics, 2014, 182(1): 119-134.

[10] Forbes, K.J. , Rigobon, R. 2002. No Contagion, Only Interdependence: Measuring Stock Market Comovements[J]. The Journal of Finance, 57(5): 2223-61.

[11] Girardi, G., Ergun, A.T., Systemic risk measurement: multivariate GARCH estimation of CoVaR[J]. Journal of Banking & Finance, 2013, 37(8):3169-3180.

[12] Hammoudeh S., Aleisa E. 2004. Dynamic Relationship among GCC Stock Markets and NYMEXOil Futures[J]. Contemporary Energy Policy, 22(2): 250-269.

[13] Henriques I, Sadorsky P. Oil prices and the stock prices of alternative energy companies[J].

[14] Huang R D,Masulis R W,Stoll H R. Energy shocks and financial markets[J]. Journal of Futures Markets,1996(1):1-27.

[15] Jones C M,Kaul G. Oil and the Stock Markets[J]. Journal of Finance,1996,51(2):463-491.

[16] Kaneko T,Lee B S. 1995,Relative Importance of Economic Factors in the U.S. and Japanese Stock Markets[J]. Journal of the Japanese & International Economies,1995(3):290-307.

[17] Kang S H., Yoon S M. 2013. Modeling and forecasting the volatility of petroleum futures prices[J]. Energy Economics, 36: 354-362.

[18] Managi S, Okimoto T. Does the price of oil interact with clean energy prices in the stock market?[J]. Japan and the World Economy, 2013, 27: 1-9.

[19] Park, J., Ratti, R.A., Oil price shocks and stock markets in the US and 13 European countries[J]. Energy Economics, 2008, 30(5):2587-2608.

[20] Reboredo J C. Is there dependence and systemic risk between oil and renewable energy stock prices?[J]. Energy Economics, 2015, 48: 32-45.

[21] Reboredo J,Ugolini,A. The Impact of Energy Prices on Clean Energy Stock Prices. A Multivariate Quantile Dependence Approach[J]. Energy Economics,2018,76:136-152.

[22] Sadorsky P. Oil price shocks and stock market activity[J]. Energy economics, 1999, 21(5): 449-469.

[23] Sadorsky P. Modeling renewable energy company risk[J]. Energy Policy,2012,40:39-48.

[24] Sadorsky P. Correlations and volatility spillovers between oil prices and the stock prices of clean energy and technology companies[J]. Energy economics, 2012, 34(1): 248-255.

[25] Uddin, G.S., Rahman, M.L., Hedstrom, A., Ahmed, A., Cross-quantilogram-based correlation and dependence between renewable energy stock and other asset classes[J].Energy Economics, 2019, 80:743-759.

[26] Wen X, Guo Y, Wei Y, et al. How do the stock prices of new energy and fossil fuel companies correlate? Evidence from China[J]. Energy Economics, 2014, 41: 63-75.

[27] Zhang D. Oil shocks and stock markets revisited: measuring connectedness from a global perspective[J]. Energy Economics, 2017, 62: 323-333.

[28] Zhang,Y. and J. Chevallier,et al. (2017). "De-financialization" of commodities? Evidencefrom stock, crude oil and natural gas markets." Energy Economics 68 (oct.): 228-239.