# Research on Public Opinion of "Double Carbon" Policy and Spillover Effect of Futures Index of Three Major Sectors——Evidence from China

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**Abstract:**To supplement the empirical research on the impact of "double carbon" policy on social economy from the perspective of online public opinion, the "double carbon" policy public opinion index is constructed with the help of search engine Baidu and the VAR-BEKK(DCC)-GARCH(1,1)model is used to scientifically quantify the spillover effect of "double carbon" policy public opinion and metal, chemical and agricultural futures index. The results show that there are one-way mean spillovers and volatility spillovers on the metal index and agricultural index of the "double carbon" policy public opinion index, and the impact of the "double carbon" policy public opinion has a short-term amplification effect, but the long-term effect is not significant. There are one-way mean spillovers and two-way volatility spillovers between the energy index and the public opinion index of the "two-carbon" policy, indicating that the energy index is most closely related to the public opinion of the "double carbon" policy, and it has strong pricing power. At the same time, it has the function of transmitting public opinion signals to traders. Based on the above findings, from the two levels of government and enterprise, suggestions are put forward, such as "stability first" macro policy, avoiding "sports" carbon reduction, and doing a good job of public opinion monitoring related to "double carbon" policy, and using it to monitor and predict the changes of related indexes.

**Keywords:** Double carbon policy;Futures price;Spillover effect;Public opinion index; VAR-BEKK(DCC)-GARCH(1,1)

## 1 Introduction

In September 2020, President Xi Jinping set forth the target of achieving carbon peaking by 2030 and carbon neutrality by 2060. The accomplishment of the "dual-carbon" objective demands proactive collaboration from all regions and sectors, and diligent guaranteeing of its accomplishment within the time frame specified, alongside unwavering efforts to forestall the formation of industry price bubbles. Previous research has concentrated on developing targeted policies, analyzing feasibility and identifying optimal pathways in the context of "dual-carbon" [1-2]. Owing to the delayed establishment of the domestic carbon market and the associated shortage of appropriate financial instruments, most entity companies adopt a wait-and-see approach towards carbon market transactions. In the context of the "dual-carbon" policy, the

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key transaction agents will still encounter the challenge of volatile prices of fundamental raw materials [3-4]. Research evidences the beneficial use of futures contracts and other financial derivatives for hedging by real businesses to effectively combine the current period in order to mitigate the risks associated with commodity price fluctuations [5]. The futures market employs a more specialized organizational system, facilitating commodity traders' prioritization of futures trading, including rights trade, basis trade and other derivative behaviours. The futures market plays a significant role in hedging price risks and contributes to achieving the crucial "dual-carbon" goals of financial derivatives.In the current context of big data, new events pose a risk of influencing social public opinion through online media dissemination and, in turn, altering market trading expectations [6-7]. Thus, it is prudent to establish precise metrics using search engine data to quantify such events. This study utilises the implementation of the "dual-carbon" policy as a metric and the commodity futures market as an entry point. With the assistance of the search engine Baidu, a public opinion index for the "dual-carbon" policy is developed. The VAR-DCC-GARCH-BEEK model is constructed to examine the spillover effect and calculate the objective price impact and volatility evolution of the "dual-carbon" policy on the metal, energy, chemical, and agricultural product sectors.

## 2 Literature Review

Futures price volatility is the research focus of scholars and commodity futures investment researchers from all circles. Existing literature studies mainly focus on three aspects: influencing factors of futures price volatility, transmission of futures price volatility, and characteristics of effect futures price volatility. This paper will sort out existing studies from these three aspects.

When examining the influencing factors of futures price volatility, the first branch of literature analyses market transactions. Qian et al. [8] contend that the speculative behaviour of international funds will intensify short-term fluctuations in futures market prices. Zhu and colleagues [9] investigated the specific relationship between price volatility, turnover and position volume by constructing a volume-price relationship model. Prior research has focused on market lobbying, investment funds and irrational factors, such as investor sentiment, to capture market reactions. However, it has overlooked the triple attributes of commodities as resources, commodities and finance. To address this issue, researchers have conducted a more comprehensive secondary literature review from varied perspectives, including supply and demand, financial markets, and economic policies. Zhong et al. [10] contend that the non-linear characteristics of metal prices are caused by a combination of supply and demand factors and financial factors. Huang et al. [11] examine the differences between the monetary policies and their effects on regulating non-ferrous metal prices. Chen et al. [12] suggest that monetary policy has the potential to alter economic growth, supply, and demand for commodities, and thus indirectly impact commodity prices. According to Zhu et al. [13], the launch of the pilot RMB settlement by China in July 2009 resulted in a unidirectional non-linear causal relationship between RMB internationalization and aluminum price changes.

Research into the transmission effects of fluctuations in futures prices has predominantly centred on the vertical transmission of prices along the industrial chain, as well as the relationship between futures and cash prices, and cross-market connections in three directions. Earlier studies had concentrated on the investigation of vertical price transmission mechanisms within the industrial chain, gradually extending their focus towards additional factors, including external events. Zhang Liziang and Zhang Xicai [14] examined the transmission mechanism of spot prices in China's agricultural industry chain through the introduction of external shocks. However, the study did not specifically quantify the external shocks. Liu et al.[15] improved on this by creating the African swine fever public opinion index. Scholars are increasingly aware of the economic risks caused by national policy instability. Baker et al's Economic Policy Uncertainty Index [16] has generated new research ideas for scholars. With the futures market becoming more mature, scholars focus mainly on researching cross-market links and relationships between periods and cash [17-18].

Various econometric models provide divergent insights on the volatility characteristics of futures prices. These theories can be categorized broadly into two distinct groups. One area of research involves analyzing the mean spillover (first-order moments of return) between non-ferrous metal prices and the carbon market. According to Han and Jiang [19], a time-varying and asymmetric spillover effect exists between these two markets, as demonstrated through TVP-VAR analysis. Additionally, Yan et al. [20] examine the transmission mechanism between the carbon emission price and coal futures price using the VEC model, impulse response, and other approaches. A further aspect for analysis is the examination of volatility spillovers, specifically the second-order moments of return. To assess the spillover effects of each carbon market pilot in China, Wang Qian and Gao [21] utilised VAR-GARCH-BEKK. Wang and Yang [22] determined a connection between the carbon market, commodity market, and financial market through their exploration using VAR and D-Y model studies.

Currently, extensive academic research has been conducted regarding price fluctuations within the futures market. However, additional research perspectives are needed, including examining the use of network public opinion as a reflection of market traders' concerns for the "dual-carbon" policy and mood changes as potential market risk factors. Through this, the impact on futures price returns and market fluctuations can be studied, along with any disparities. However, there is scarce literature on this subject matter, with limited related studies available.

## 3 Theoretical Analysis

For the concept of the "spillover effect" on prices, its operational mechanisms have been explained by both rational expectation theory [23] and market contagion theory [24]. The rational expectation theory suggests that market traders will use all available information to make informed trade decisions or adjustments that maximize their profits. The market contagion theory posits that as the financial system rapidly evolves, the degree of market interdependence increases. In the event of a specific risk, this can provoke emotional fluctuations and other irrational behavior among traders. In some cases, it can even trigger the so-called "herd effect" in financial markets, leading to significant price fluctuations. From the present pricing performance features of China's financial market, it is evident that the two theories synergistically complement each other and function collectively within the market. In the current financial landscape with a complex convergence of systems, occurrences such as events, risk factors, or changes in market information will be communicated between retail investors and institutional traders, who are responsible for macro-control of special institutions, securities, futures, fund companies, industrial capital, and other professional entities. Multiple interests coexist within the market trading system, leading to individual and institutional traders with significant market shares seeking to maximise their profits based on rational expectations and/or irrational factors driven by trading sentiment. These factors influence decision-making regarding multi-market or single-market trading, which in turn can trigger market price fluctuations.Under the backdrop of the "dual-carbon" policy, the key sectors for achieving the policy goals are metal, energy and chemical, and agricultural products. The proposal and implementation of the policy will lead traders to alter their focus and understanding of policy-related issues, which will be reflected in time-series "public opinion indices" in the context of the Internet. This will enable the manifestation and quantification of relevant responses. Under the joint influence of irrational factors, such as rational expectations and market sentiment, individuals may engage in hedging or speculative behaviours by either buying or selling, resulting in corresponding price fluctuations.

# 4 Methods and Data

## 4.1 Methods

In this paper, the VAR model is selected to analyze the mean spillover effect between the public opinion index of "double carbon" policy and the futures index of metal, chemical and agricultural sectors. The VAR model is specifically expressed as:

$$Y_t=C+A_1Y_{t-1}+A_2Y_{t-2}+\ldots+A_pY_{t-p}+B_1X_{t-1}+B_2X_{t-2}+\ldots+B_nX_{t-n}+\varepsilon_t \tag{1}$$

Building upon the aforementioned VAR model, we employ the BEKK model to investigate the spillover effects of volatility across variables. The following is the resulting model.

$$H_t=CC'+A\varepsilon_t\varepsilon_t'A'+BH_{t-i}B' \tag{2}$$

$$H_t=\begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix} \quad C_t=\begin{bmatrix} c_{11,t} & 0 \\ c_{21,t} & c_{22,t} \end{bmatrix} \quad A_t=\begin{bmatrix} a_{11,t} & a_{12,t} \\ a_{21,t} & a_{22,t} \end{bmatrix} \quad B_t=\begin{bmatrix} b_{11,t} & b_{12,t} \\ b_{21,t} & b_{22,t} \end{bmatrix} \tag{3}$$

Where，C is the lower triangular matrix, matrix A and B represent ARCH and GARCH term coefficients, aii and bii (i,j=1 or 2) represent ARCH and GARCH effects of time series' own fluctuations, respectively. aij and bij (i≠j) represent the ARCH effect and GARCH effect of volatility between the two markets, respectively.

At the same time, in order to further observe the linkage between the two, the DCC-GRACH model is established on the basis of the above VAR model, and the dynamic correlation coefficient of each variable is calculated. The specific process is as follows:

$$\varepsilon_t/I_{t-1}\sim N(0,H_t) \tag{4}$$

$$\varepsilon_t=(\varepsilon_{1,t},\ \varepsilon_{2,t},\ \ldots,\ \varepsilon_{i,t}) \tag{5}$$

$\varepsilon_t$ is the residual vector, $I_{t-1}$ is the T-1 period information data set, $H_t$ is the conditional covariance matrix. Do the following for Ht:

$$H_t=D_tR_tD_t \tag{6}$$

$$D_t=diag\sqrt{h_{i,t}} \tag{7}$$

$$R_t=(Q_t^*)^{-1}Q_t(Q_t^*)^{-1} \tag{8}$$

$$Q_t=S(1-\delta_1-\delta_2)+\delta_1\varepsilon_{t-1}\varepsilon_{t-1'}+\delta_2Q_{t-1} \tag{9}$$

Where, $D_t$ is the diagonal matrix of conditional standard deviation; $R_t$ is the dynamic conditional correlation coefficient matrix; $Q_t$ is the conditional covariance matrix of standardized residuals, S is the unconditional variance matrix of standardized residuals, $\delta_1$ is the ARCH term coefficient, $\delta_2$ is the GARCH term coefficient, and $0\le\delta_1$, $0\le\delta_2$, $0\le\delta_1+\delta_2\le1$.

### 4.2 Data

Since the SCMFI is a primary index that classifies three major sectors - metals, energy and chemical, and agricultural products - it provides a comprehensive overview of futures prices by including both the highest and lowest futures prices of the main contracts for each variety, as well as the other non-main futures contracts. As a result, we have opted to utilise the indexes for metals, energy and chemical, and agricultural products within the SCMFI. The paper's focus is on the spillover effect of public opinion concerning the "dual-carbon" policy on commodity futures prices. Thus, a "dual-carbon" policy public opinion index is constructed to quantify said policy. Considering the timeliness and availability of the above data, the daily data from 23rd September 2020 to 8th July 2022 have been selected for the sample. Non-common date data of the sample data sets have been excluded, resulting in 433 data sets. The South China Metals, Energy and Chemical, and Agricultural Products indices are from WIND, while the "Dual Carbon" Public Opinion Index is from Baidu Index. Further details are provided below:

(1) Public Opinion Index of "Dual-Carbon" Policy: Using big data sourced from the internet, we have developed a set of quantitative time-series indicators, which depict the public's attention towards the "Dual-Carbon" policy. We employed the Baidu index platform to select keywords related to "Dual-Carbon," which aided us in mapping public demand. Our analysis yielded eight critical keywords, including "dual-carbon," "carbon neutral," "carbon peak," etc. that emphasise the centrality of "Dual-Carbon". The text already adheres to the given principles and lacks context. Therefore, the answer is: 'The following eight keywords were identified: first, "dual-carbon", "carbon neutral", "carbon peak" and other keywords reflecting the name of "dual-carbon"; second, "carbon trading", "carbon sink", "low carbon", "energy saving and emission reduction", and "energy efficiency".' The second category comprises "carbon trading", "carbon sink", "low carbon", "energy efficiency and emissions reduction", "dual control of energy consumption", and other key terms relating to "dual carbon" policy measures and public concerns. The gathered data is then summed and logarithmically processed, with the resulting indicator being assigned the variable y. The formula for its specific calculation is as follows:

$$y=ln(X_1+X_2+\ldots+X_n) \quad (10)$$

(2) Metal index: including 12 varieties, specifically rebar, iron ore, hot rolled coil, wire, manganese silicon, ferrosilicon, copper, aluminum, nickel, zinc, lead, tin, the index is set as $r_1$;

(3) Energy index: contains 13 varieties, specifically natural rubber, coke, crude oil, thermal coal, polyethylene, PTA, coking coal, polypropylene, glass, petroleum asphalt, PVC, methanol, fuel oil, the index is set as $r_2$;

(4) Agricultural product index: contains 19 varieties, specifically soybean meal, sugar, soybean oil, palm oil, soybean, corn, cotton, rapeseed oil, egg, corn, rapeseed meal, early indica rice, late indica rice, strong wheat, japonica rice, plain wheat, apple and cotton yarn. The index is set at $r_3$.

In order to eliminate the unstationarity, the above data are processed as follows:

$$r_t=100\times ln(p_t/p_{t-1}) \quad (11)$$

# 5 Empirical Results

## 5.1 Descriptive statistics

Table 1 shows the descriptive statistical results of the study variables. In terms of the mean value, the mean value of each time series was greater than 0, indicating that all time series were in an overall rising stage during the sample period. Among them, the public opinion index of "double carbon" policy (y) increased the most, followed by the energy index ($r_2$), agricultural product index ($r_3$) and metal index ($r_1$). In terms of standard deviation, "double carbon" policy public opinion index (y) > metal index ($r_1$) > energy index ($r_2$) > agricultural product index ($r_3$). Therefore, the public opinion index of "double carbon" policy has the largest fluctuation, and the volatility of high-carbon sectors such as metals and energy is greater than that of agricultural products and low-carbon sectors under the background of "double carbon" policy. In terms of skewness and kurtosis, all time series are right-skewed and have the characteristics of sharp peaks and thick tails. In terms of J-B statistics, each time series is significantly different from the normal distribution. ADF test results show that each time series is stationary state. Ljung-Box statistic test results show that the policy of "double carbon" public opinion index (y) serial correlation exists, and the rest of the time sequence does not have the auto-correlation.Figure1 shows the time series diagram of the rate of return of each time series, which can be observed intuitively:Column fluctuations show obvious differences in different time periods, that is, they are time-varying; In addition, it also has the characteristics of wave aggregation, that is, a large wave.The movement follows another big fluctuation; One small fluctuation is followed by another.

**Table1.** Descriptive statistics Results

| | Mean | Std.DeV | Skewness | Kurtosis | Jarque-Bera | Q(5) | Q(10) | ADF |
|---|---|---|---|---|---|---|---|---|
| y | 0.2606 | 18.3894 | -0.1773 | 20.7579 | 5599.63 | 16.235*** | 16.961* | -23.7860*** |
| $r_1$ | 0.0733 | 5.0770 | -0.3203 | 3.3915 | 10.0084 | 2.5808 | 5.8979 | -20.7523*** |
| $r_2$ | 0.1463 | 1.6116 | -0.1986 | 4.0966 | 24.1509 | 1.6915 | 7.3121 | -20.5626*** |
| $r_3$ | 0.0823 | 0.8441 | 0.2319 | 4.3021 | 33,9161 | 2.2315 | 15.715 | -20.5920*** |

Notes: *, **, *** denote statistical significance levels at 10%, 5% and 1% respectively.

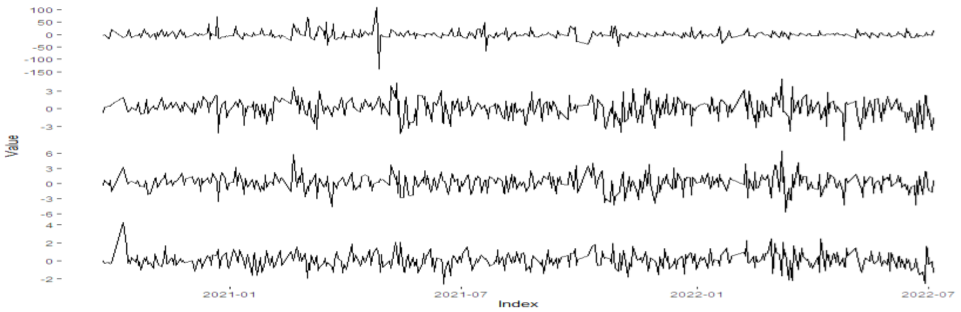
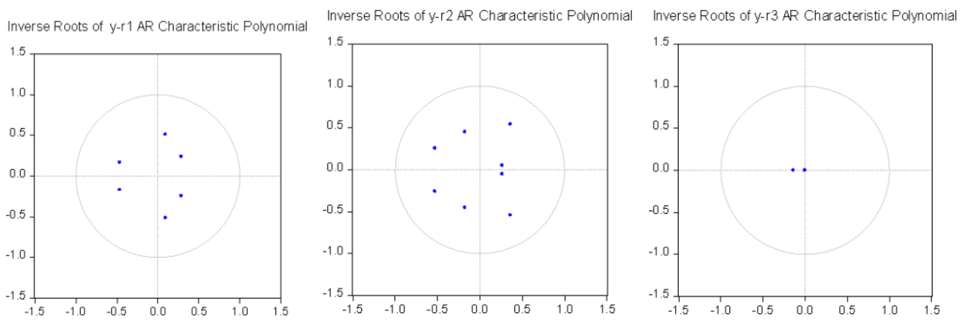


**Figure1.**Time series sequence diagram

## 5.2 Analysis of mean spillover effect

According to the AIC statistical criterion, the optimal lagorder of the public opinion index (y) and metal index ($r_1$) of "double carbon" policy is calculated as 3, the optimal lag order of the binary VAR model with energy index ($r_2$) is 4, and the optimal lag order of the binary VAR model with agricultural product index ($r_3$) is 1. Meanwhile, it can be observed from Figure 2 that all unit roots lie within the unit circle, which provides evidence to suggest that the model is well-established.



(a) (b) (c)

**Figure2.** Inverse Roots of AR Characteristic Polynomia

On the basis of the above VAR model, Granger causality is used to test the mean spillover effect between public opinion index (y) of "two-carbon" policy and metal index ($r_1$), energy index ($r_2$) and agricultural index ($r_3$). The results are shown in Table 2.

**Table 2**. Results of Granger causality test

| H0 | F value | P value | results | H0 | F value | P value | results |
|---|---|---|---|---|---|---|---|
| y is not the Granger causality of $r_1$ | 2.2489 | 0.0804 | Refused | $r_1$ is not the Granger causality of y | 0.6711 | 0.5697 | Accept |
| y is not the Granger causality of $r_2$ | 1.4804 | 0.2051 | Accept | $r_2$ is not the Granger causality of y | 2.0193 | 0.0887 | Refused |
| y is not the Granger causality of $r_3$ | 3.6696 | 0.0554 | Refused | $r_3$is not the Granger causality of y | 0.0038 | 0.9505 | Accept |

Notes: *, **, *** denote statistical significance levels at 10%, 5% and 1% respectively.

According to Table 2, the public opinion index (y) of "double carbon" policy is Granger cause of metal index ($r_1$) and agricultural product index ($r_3$) at 10% significance level, and the energy index ($r_2$) is Granger cause of public opinion index (y) of "double carbon" policy at 10% significance level. The results show that there is one-way mean overflow of the "two-carbon" policy public opinion index (y) to the metal index ($r_1$) and agricultural index ($r_3$), and one-way mean overflow of the energy index ($r_2$) to the "two-carbon" policy public opinion index (y). This mainly shows that the public opinion of "double carbon" policy and the future change of metal futures index and agricultural futures index have a certain interpretation and prediction role, and there is a certain "leading and lagging" relationship between them. The energy futures index has strong overall pricing ability and plays a role in transmitting public opinion signals to traders.

In order to further study the specific relationship between the variables in the model, impulse response function is used to analyze the impact evolution process of the public opinion index (y) of the "double carbon" policy on each variable, and the results are shown in Figure 3.

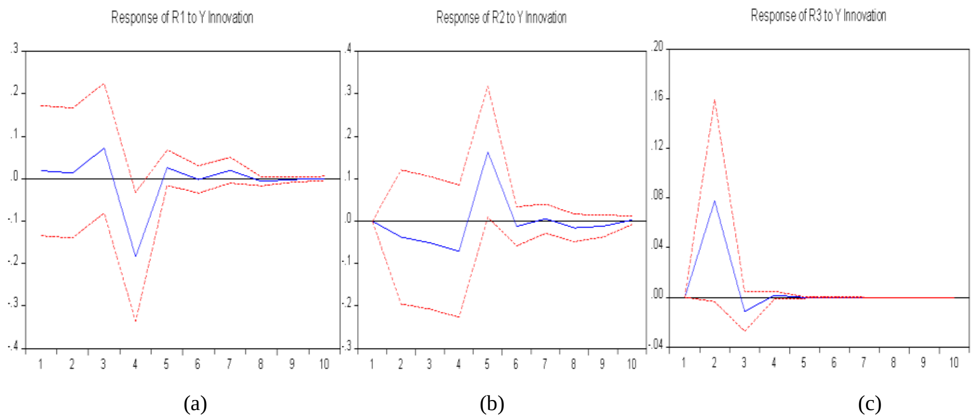



**Figure3.** Results of Impulse response

When the "two-carbon" policy public opinion index (y) was impacted by one unit standard deviation in this period, the metal index ($r_1$) showed a positive response of first increasing and then decreasing, and then showed a negative response of first increasing and then decreasing, and gradually approached the 0 axis. When the "two-carbon" policy public opinion index (y) was impacted by one unit standard deviation in the current period, the energy index ($r_2$) showed a slightly increasing negative response from the first period to the fourth period, and then showed a positive response that increased first and then decreased, and approached the 0 axis. When the "two-carbon" policy public opinion index (y) is impacted by one unit standard deviation in the current period, the agricultural product index ($r_3$) shows a positive response of first increasing and then decreasing in the short term, and then rapidly converges to the 0 axis after the fourth period.

According to the above results, it can be found that the public opinion index (y) of "dual carbon" policy has a certain impact on the above three futures price indexes in the short term, and the impact degree will be enlarged. However, when the time span is extended, the impact will be slowed down and reverse impact will occur. The reaction on the disk shows that the public opinion on the "double carbon" policy will cause a wave of large levels of rise or fall in relevant futures prices, and then reverse in different directions, rather than a sustained unilateral trend, and the level of market reversal will weaken gradually. At the same time, the public opinion index (y) of the "double carbon" policy has different impact on different futures price indexes, showing a small positive impact on agricultural product index ($r_3$) as a whole, while there are certain differences in impact effects on metal index ($r_1$) and energy index ($r_2$). According to the reporting period of the selected data in the research, it is found that: In 2021 as a "double carbon" policy of the first year of target is put forward, in the short term market deepened concern in the "double carbon" policy, to the goods, their own industry resources endowment scarcity under the background of "double carbon" policy at the early stage of the "double carbon" put forward by the policy goal, policy centered to reduce carbon emissions set goals, For high-carbon emission energy enterprises, it is necessary to put forward strict environmental assessment and approval control of "two-high" projects and encourage energy-saving, green and high-quality development of the industry. Energy demand-side management has become an important starting point for the country to achieve the "two-carbon" goal. Therefore, public opinion on "two-carbon" policy has a negative impact on the energy sector in the early stage. For metal plate, from the state to carry out the "double carbon" specific policy measures, such as energy consumption of the double control policy, although the full-year target in time, but the overall lack of flexibility, individual local governments index finished early, lead to some industry appeared in the process of policy implementation centralized production, resulting in metal prices have rise in price, However, after the realization of the policy goals, the policies of ensuring supply, increasing production and stabilizing prices frequently come out, resulting in a negative feedback between the development of the metal industry and the national policies of carbon reduction and stabilizing prices. Second, the double carbon policy target for the metal industry, reducing output as the key requirements. In 2021, under the background of "double carbon" policy, the strong centralized production reduction policy in the second half of the year makes steel mills mostly in the state of unsaturated production, repair or production suspension, which makes some metal raw material demand expected to be suppressed by stages, and the market will to suppress raw materials, making metal prices in the later stage of pressure.

### 5.3 Analysis of volatility spillover effect

On the basis of the above VAR, Ljung-Box and the ARCH-LM inspection. The results in Table 3 show that most of the time series have eliminated linear dependence at this time, and have significant ARCH effect, which meets the requirements of GARCH family modeling.

**Table 3.** Auto correlation and ARCH test

| | y-$r_1$VAR(3)residual | | y-$r_2$VAR(4)residual | | y-$r_3$VAR(1)residual | |
|---|---|---|---|---|---|---|
| | y | $r_1$ | y | $r_2$ | y | $r_3$ |
| Q(5) | 8.2699 | 0.5557 | 1.9738 | 0.1241 | 13.3076** | 1.6658 |
| Q(10) | 9.1048 | 4.4954 | 2.3817 | 3.5644 | 14.1874 | 15.1663 |
| ARCH-LM(5) | 124.1058*** | 22.6944*** | 118.2200*** | 35.6079*** | 122.4591*** | 13.8467** |
| ARCH-LM(10) | 125.6845*** | 32.9848*** | 120.2282*** | 43.3040*** | 124.1003*** | 18.0143* |

Notes: *, **, *** denote statistical significance levels at 10%, 5% and 1% respectively.

Meanwhile, according to the results in Table 4, all single variable GARCHA (1,1) meet $0 < \gamma+\delta < 1$, and the parameters are significant, indicating that the model setting meets the requirements, where $\gamma$ is the ARCH term coefficient and $\delta$ is the GARCH term coefficient. Then the ARCH-LM effect test was carried out, and the results showed that heteroscedastic features had been fully extracted and the model was robust.

**Table 4.** Conditional single variable GARCH(1,1)

| | y-$r_1$ | | y-$r_2$ | | y-$r_3$ | |
|---|---|---|---|---|---|---|
| | y | $r_1$ | y | $r_2$ | y | $r_3$ |
| Φ | 54.4103** | 0.1106* | 45.5179* | 0.2288 | 64.9789** | 0.0010 |
| γ | 0.5017** | 0.1230*** | 0.4477** | 0.0853** | 0.5689** | 0.0000 |
| δ | 0.4273*** | 0.8420*** | 0.4661*** | 0.8267*** | 0.3637* | 0.9990*** |
| ARCH-LM(5) | 4.2292 | 2.500 | 4.4905 | 4.930 | 4.5278 | 0.7851 |
| ARCH-LM(7) | 5.1385 | 2.899 | 5.2897 | 6.067 | 5.5233 | 1.1289 |

Notes: *, **, *** denote statistical significance levels at 10%, 5% and 1% respectively.

On the basis of the above, this paper adopts the BEKK-GARCH (1,1) model to analyze the volatility spillover effect between the public opinion index (y) of "double carbon" policy and the indexes of metals, energy and agricultural products. The results are shown in Table 5.

**Table 5.** Results of  Fluctuation overflow

| Panel A：Results of BEKK-GARCH | | | |
|---|---|---|---|
| | y-$r_1$ | y-$r_2$ | y-$r_3$ |
| $a_{11}$ | 0.6003*** | 0.7260*** | 0.6737*** |

| | | | |
|---|---|---|---|
| $a_{12}$ | -0.0031 | -0.0021 | -0.0000 |
| $a_{21}$ | -0.8197 | 1.7520** | -0.6275 |
| $a_{22}$ | -0.3215*** | -0.2048*** | -0.2129*** |
| $b_{11}$ | -0.6287*** | 0.4624*** | 0.5951*** |
| $b_{12}$ | 0.0112*** | -0.0106** | -0.0120** |
| $b_{21}$ | -0.3681 | -0.4889 | -2.0502* |
| $b_{22}$ | 0.9479*** | 0.9663*** | -0.9372*** |
| $c_{11}$ | 6.6962*** | 7.7943*** | 6.6934*** |
| $c_{21}$ | -0.1029 | 0.0585 | -0.1134 |
| $c_{22}$ | 0.1236 | 0.2039 | 0.1999** |

Panel B：Wald test

| | $y-r_1$ | $y-r_2$ | $y-r_3$ |
|---|---|---|---|
| $H_0$ | $H_0$:$a_{12}$=$b_{12}$=0<br>Wald：5.1423*** | $H_0$:$a_{12}$=$b_{12}$=0<br>Wald：3.3613** | $H_0$:$a_{12}$=$b_{12}$=0<br>Wald：2.3469* |
| $H_1$ | $H_1$:$a_{21}$=$b_{21}$=0<br>Wald：1.4347 | $H_1$:$a_{21}$=$b_{21}$=0<br>Wald：3.5081** | $H_1$:$a_{21}$=$b_{21}$=0<br>Wald：1.6507 |

Notes: *, **, *** denote statistical significance levels at 10%, 5% and 1% respectively.

As can be seen from Table 5, the public opinion index (y) of "double carbon" policy, metal index ($r_1$), energy index ($r_2$) and agricultural index ($r_3$) have ARCH effect and GARCH effect on their own fluctuations, and the fluctuations of each index have agglomeration and persistence. In terms of volatility spillover between public opinion index (y) and metal index ($r_1$) of "double carbon" policy, diagonal matrix elements $a_{11}$、$a_{22}$、$b_{11}$、$b_{22}$ are significantly different from zero at 1% significance level, and off-diagonal matrix element $b_{12}$ is significantly different from zero at 1% significance level. Combined with the Wald test results, $a_{12}$=$b_{12}$=0 is not valid at the significance level of 1%, indicating that there is one-way volatility spillover between the public opinion index (y) of the "two-carbon" policy and the metal index ($r_1$). In terms of volatility spillover of public opinion index (y) and energy index ($r_2$) of "double carbon" policy, diagonal matrix elements $a_{11}$、$a_{22}$、$b_{11}$、$b_{22}$ are significantly different from zero at 1% significance level, and off-diagonal matrix elements $a_{21}$ and $b_{12}$ are significantly different from zero at 5% significance level. Combined with the Wald test results, both $a_{12}$=$b_{12}$=0 and $a_{21}$=$b_{21}$=0 are not valid at the significance level of 5%, indicating that bidirectional volatility spillovers exist between the public opinion index (y) and the energy index ($r_2$) of the "double carbon" policy. In terms of volatility spillovers between public opinion index (y) of "double carbon" policy and agricultural product index ($r_3$), diagonal matrix elements $a_{11}$、$a_{22}$、$b_{11}$、$b_{22}$ are significantly different from zero at 1% significance level, off-diagonal matrix element $b_{12}$ is significantly different from zero at 5% significance level, and $b_{21}$ is significantly different from zero at 10% significance level. The Wald test results show that $a_{12}$=$b_{12}$=0 does not hold at the 10% significance level, indicating that there is one-way volatility spillover from the "two-carbon" policy public opinion index (y) to the agricultural product index ($r_3$).

It can be found that there is a risk transmission phenomenon between the above two markets. Therefore, when the government implements specific policies or market traders change their concentration of attention to the "double carbon" policy, the government departments or the futures hedgers of relevant enterprises should keep constant attention to the corresponding prices. The reason is that the fundamental information related to the "double carbon" policy will generate a systematic, complex and strongly correlated public opinion effect with the help of the Internet, and lead to a linkage reaction between the public opinion index of the "double carbon" policy and the commodity futures index. It is worth noting that the energy market is the market where the public opinion of "dual carbon" policy is most closely related, and the energy index ($r_2$) has volatility spillover to the public opinion index (y) of "dual carbon" policy. That is, when the futures price of energy commodity fluctuates in the futures market, the public opinion of "dual carbon" policy will change. It shows that short-term futures price volatility will obviously drive market trading sentiment spillover, and traders are more likely to verify whether the "double carbon" policy has an impact on their own industry futures price volatility. On the other hand, it also reflects the strong pricing power of the energy futures market as a whole.

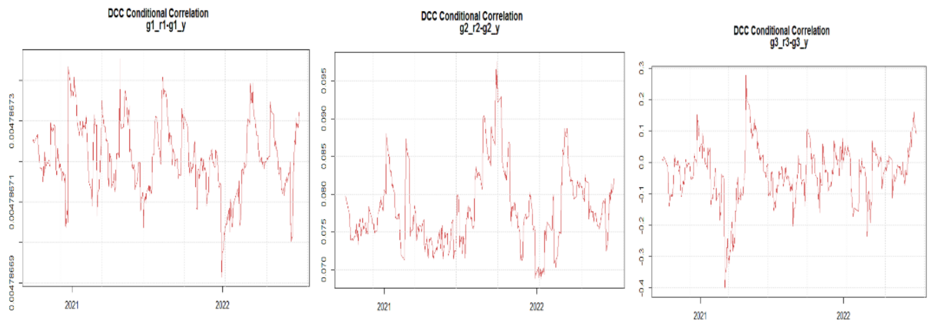
### 5.4 Dynamic correlation analysis

The DCC-GARCH (1,1) model was used to calculate the dynamic correlation coefficient between each time series, and the dynamic correlation between the public opinion of "double carbon" policy and each futures index was further studied.The outcomes are exhibited in Table 6. In the meantime, the dynamic correlation coefficients among the time series were computed, and the outcomes are presented in Figure 4, respectively.

**Table 6.** Test of dynamic correlation

| | $g_1$:y-$r_1$ | $g_2$:y-$r_2$ | $g_3$: y-$r_3$ |
|---|---|---|---|
| $\sigma_1$ | 0.0000 | 0.0018 | 0.0454 |
| $\sigma_2$ | 0.9204*** | 0.9275*** | 0.8403*** |
| $\sigma_1 + \sigma_2$ | 0.9204 | 0.9293 | 0.8857 |

Notes: *, **, *** denote statistical significance levels at 10%, 5% and 1% respectively.




(a) (b) (c)

**Figure 4.** Time series diagram of DCC conditional correlation

It can be seen from the above results that $0 < \sigma_1 + \sigma_2 < 1$, indicating that the model setting meets the requirements, but $\sigma_1$ is small and insignificant, indicating that the dynamic correlation coefficient is not affected by the product of previous standardized residuals. The value of $\sigma_2$ is more than 0.85 and is very significant, indicating that the dynamic correlation degree between the public opinion of "double carbon" policy and each futures index has a lasting influence in time. Meanwhile, the dynamic correlation between the public opinion of "double carbon" policy and each futures index is time-varying. The dynamic correlation between the public opinion index of "double carbon" policy (y) and metal index ($r_1$) and energy index ($r_2$) is positive, and the dynamic correlation between the public opinion index of "double carbon" policy and agricultural index ($r_3$) fluctuates greatly. This indicates that when the public opinion of "dual carbon" policy fluctuates, the transmission to the futures market is differentiated, and the transmission efficiency varies with time, among which the agricultural product market is more prominent.

# 6 Conclusions and suggestions

## 6.1 Conclusions

In this paper, with the help of search engine Baidu, the public opinion index of "double carbon" policy was constructed, and the VAR-GARCH-BEEK model was established respectively with metal, chemical and agricultural futures index to analyze its spillover effect. The conclusions are as follows: First, in terms of mean spillover, the "double carbon" policy public opinion index (y) has mean spillover to the metal index ($r_1$) and agricultural product index ($r_3$), and the energy index ($r_2$) has mean spillover to the "double carbon" policy public opinion index (y). Specifically, the "double carbon" policy public opinion index (y) can explain and predict the future changes of the metal and agricultural futures index to a certain extent, and has a short-term amplification effect on the price impact. However, when the time span is extended, the impact will be mitigated. At the same time, the energy sector shows strong pricing power, holding the role of transmitting public opinion signals to traders. Second, volatility spillover effect. The bidirectional volatility spillover exists in the energy index ($r_2$) of the public opinion index of "dual carbon" policy (y), and the one-way volatility spillover exists in the metal index (r1) and agricultural index ($r_3$), indicating that there is a risk transmission phenomenon among the above markets, and the energy is the market most closely related to the public opinion of "dual carbon" policy. When the government formulates specific "dual carbon" policy measures or traders participate in market transactions, we must pay attention to the linkage between public opinion of "dual carbon" policy and commodity futures market. Thirdly, in terms of dynamic correlation, the dynamic correlation between the public opinion index (y) of "double carbon" policy and each futures index has a certain time variation. The dynamic correlation between metal index ($r_1$) and energy index ($r_2$) is positive, and the dynamic correlation between them and agricultural index ($r_3$) fluctuates greatly.

## 6.2 suggestions

According to the above conclusions, this paper puts forward the following suggestions from the government and enterprise level: At the government level, the phenomenon of "campaign carbon reduction" should be firmly avoided in the first place. Put forward the policy of "double carbon", deepening must fully consider the current level of economic development in our country, at all levels of government in promoting policy, institutional, industrial, and other aspects related to the top of the design and path planning, must keep in mind the "respect for objective law, for the market main body, devoid of thinking type, curb impulse type". Specifically speaking, when implementing the "double carbon" development strategy under the current situation and taking the path of green and low carbon development, our country's macro policies should "rely on stability" at the present stage to ensure the steady operation of the economy and society. Secondly, governments at all levels should also do a good job of online public opinion monitoring related to the "double carbon" policy, grasp the law of public opinion communication, analyze the development trend of public opinion, actively guide market expectations and confidence, and use relevant public opinion changes to monitor and predict the price fluctuations of real enterprises or financial level. At the level of enterprises, they should view the development and challenges brought by the "double carbon" policy objectives from a dynamic and systematic perspective. On the one hand, they should strengthen innovation in their own technologies and mechanisms to better apply the "double carbon" policy requirements. On the other hand, they should do a good job in price risk management. Futures hedging enterprises should give full consideration to the policy of "double carbon" public opinion and their participation in the variety of hedge, industry correlation and degeneration, and on the basis of qualitative and quantitative analysis, using both specific spillover effect to predict the future, make rational hedging strategy, effectively avoid under the market rally crash hedging losses caused by risks.

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