Accounting and Corporate Management (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/acccm.2024.060520
ISSN 2523-5788 Vol. 6 Num. 5

Analysis of price dynamic spillovers between carbon and energy markets

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Keywords: China carbon market; energy market; TVP-VAR-DY model; yield spillover

Abstract: It is important to comprehensively study the characteristics of price dynamic spillovers between China's carbon market and energy market, and fully understand the mechanism between energy prices and carbon prices. The spillover index model is used for the period from September 1, 2015 to September 2022. The spillover effect between the price yield of China's carbon market and the energy market is measured on the 1st. The results show that the price-yield spillover level of China's carbon market is low in the spillover system with the energy market, and the impact of carbon price changes on traditional energy markets such as crude oil and coal is strong. At the same time, the spillover direction is asymmetrical, and there are significant differences and time-varying characteristics of the spillover effect between different energy markets and carbon markets, and the special periods and special events of the economy and society will also have a great impact on the degree of the spillover effect.

1. Introduction

As the world's largest energy consumer and carbon dioxide emitter, China attaches great importance to the energy and environmental problems brought about by carbon emissions, and actively participates in the construction of a global climate governance system. The carbon market is recognized as an effective policy tool to control global carbon emissions, which will have a wide and far-reaching impact on the energy supply and demand structure, and the establishment of the carbon emission trading market provides an economic solution for the reduction of carbon emissions [1].It is of great significance to international carbon emission governance to establish and maintain a sound national carbon market and promote China's national economic growth to gradually move away from the growth model of high energy consumption, high pollution, and high capital consumption [2].

As China's carbon market continues to grow rapidly, energy or carbon market fluctuations caused by information shocks can easily propagate between the two types of markets, resulting in enhanced network interoperability. As a key driver of carbon pricing, changes in energy prices will have a direct impact on carbon emissions and the demand for carbon emission allowances [3].With the gradual expansion of the scale of carbon trading and the gradual maturity of the carbon emission trading system, scholars at home and abroad have conducted multi-dimensional and multi-faceted research on the carbon emission trading market, and some scholars have based on Diebold-YilmazThe spillover index analyzes the spillover effects between the carbon market and the energy market. The study found that there is a price correlation between the energy market and the carbon trading market

[4]. Ouyang Gelaoxin (2017) aimed at the main factors affecting the price in China, and the results of the study based on structural equation modeling showed that energy prices, policies, and climate prices can affect the carbon price, of which energy prices have a significant impact on the carbon price [5]. Zhang et al. (2010) found that there is a significant long-term equilibrium cointegration relationship between the price of fossil energy and the price of carbon emission rights through the establishment of a VAR model as well as a state-space model, and the fluctuation of the carbon price is most affected by the price of crude oil [6]. Zhao Yihang and Zhao Huiru (2024) pointed out that there is a significant one-way mean spillover effect between the carbon market and all types of fossil energy markets in the pilot stage [7]. Existing literature mostly adopts GARCH model and spillover index method to measure the spillover effect. Liu Jianhe et al. (2021) used the DCC-GARCH model to measure the spillover between the traditional energy market and China's carbon market, and explored the impact of the U.S.-China trade war [8]; Zhao et al. (2021) used the spillover index model to analyze the volatility of carbon and energy prices in the studied time period, and showed that there is a bi-directional fluctuation spillover effect between the carbon price and the energy price and the spillover effect between the carbon and energy markets in different regions [9]. There are differences in the characteristics of the spillover effect and the spillover relationship between the carbon market and the energy market in different regions [9].Wang Xiping (2023) constructed a spillover index network model research found that carbon and energy markets in various industries between the risk spillover intensity of the fossil energy industry in the strong, followed by the secondary energy industry and finally the new energy industry [10].

In view of the above situation, the comparative analysis of the spillover effect between the carbon market and different energy markets, and the in-depth investigation of the time-varying fluctuation spillover characteristics between China's carbon market and the energy market, are essential for further promoting China's carbon market. It is of great significance to reasonably form an intrinsic price transmission mechanism with the energy market, prevent rapid fluctuations in carbon prices, and promote the stable operation of China's carbon trading system.

2. Mechanism analysis and empirical design

2.1. Analysis of spillover mechanism

As we all know, due to the incomplete asymmetry of information between markets, the development of a market will not only have an impact on itself, but also have different degrees of impact on other markets, that is, there is a spillover effect [11]. With the global management and control of carbon dioxide emissions, the carbon emissions system system is increasingly perfect, the carbon market shows the financial attributes continue to increase, so that the carbon market and other financial markets, commodity markets are becoming increasingly close to each other, there is a different intensity of the impact of the effect between each other, and the spillover effect itself is a cross-market dissemination of information phenomenon. More and more studies point out that the fossil energy market, carbon market, clean energy market are not efficient markets [12], the relationship between carbon market and the energy market, there is a strong external spillover effect between each other. Changes in energy prices will directly affect the production costs of enterprises, especially for those industries that consume large amounts of energy, such as electricity, steel and so on. When energy prices rise, the production costs of enterprises increase, and in order to maintain profits, enterprises may consider reducing energy consumption or improving the efficiency of energy utilization, thus reducing carbon emissions. This emission reduction behavior will increase the supply of carbon emission rights in the market, which in turn will have an impact on the trading price of carbon emission rights. In addition, the price difference between different energy sources will also lead enterprises to choose lower-cost energy sources. When the price of coal is high, enterprises may

choose to use alternative energy sources such as natural gas or renewable energy sources, thus reducing coal consumption and carbon emissions, and this substitution effect will also indirectly affect the trading price of carbon emission rights. The government's policy formulation and adjustment in the carbon and energy markets will also have an impact on the price spillover effect between the two.

The spillover effect between the carbon market and energy market is a complex and multi-dimensional phenomenon, which is not only reflected in the supply and demand relationship, price transmission, policy influence, etc., but also special external events will have a strong or weak impact on the spillover relationship between the markets.

2.2. Variable Selection and Data Description

So far, China has established nine regional carbon markets, and the national carbon market has been officially listed and traded since 2021. In order to maximize the use of the effective information of each market, this paper takes the daily carbon emission trading volume of each regional carbon emission trading market as the weight. A national carbon emission trading price index based on the regional carbon emission market and the national carbon market was constructed, and the weighted average daily trading price of the regional carbon market and the carbon price of the national market was obtained. The national average price of carbon emission allowances based on the trading data of all carbon emission trading markets can effectively avoid the problem of sample selection bias representing the national carbon emission allowance market in a single region, and prevent partial generalization.

Combined with the current energy consumption structure and data availability in China, the data selection of the energy market mainly selects coal, crude oil, natural gas and liquefied gas, which account for a large proportion of China's energy consumption system: the thermal coal futures market of Zhengzhou Commodity Exchange represents the coal market, The closing price of futures represents the price of coal (COAL); the oil market is represented by the Brent Crude Oil Market (BCOM), and the spot price of BCOM represents the price of oil (BOCA); and the price of oil is represented by the price of BOCA. Spot price on behalf of the oil price (BRENT); The NYSE natural gas futures market represents the natural gas market, and the closing price of NYMEX natural gas futures is ghosted for the natural gas price (GAS); The Liquefied Gas Price Index represents the price of liquefied gas (LPG). At the same time, the development of the carbon market and the guidance of national policies will inevitably affect the change of energy consumption structure, thereby promoting the innovation of new energy technologies. The link between the carbon market and the new energy industry is also crucial, so the New Energy Index (NER) has been introduced to measure how there are spillovers between the carbon market and the new energy market.

Due to the fact that the price dates of each market index are not completely consistent, the sample data is screened to eliminate blank data and invalid data to ensure the continuous consistency of each series. In order to ensure the stationarity of the sample data, the first-order difference is performed on each time series, and the original price data is converted into a logarithmic return series, and the formula is as follows:

$$R_t = \ln(P_t / P_{t-1}) \times 100$$

According to the availability of data, the data period was selected from September 1, 2015 to September 1, 2022. The above data is from the Wind database. Table 1 shows the descriptive statistics of the data for these six variables, *, **, respectively10%, 5%, 1% significant at the level.

Table 1: Descriptive statistics of variables

	CARBON	COAL	BRENT	GAS	LPG	NER
Mean	0.1328	0.0308	0.0630	0.0936	0.01717	0.0599
Median	0.0830	0.0679	0.1775	0.0504	0.0469	0.0324
Max	188.9777	10.9615	22.8367	33.8757	6.5610	7.7862
Min	-170.3275	-21.7710	-37.1619	-22.9661	-7.4276	-7.5707
Std. Dev	35.9290	2.3142	3.1732	3.7108	1.5145	1.8658
Skewness	0.01014	1.6818	1.3869	0.4697	0.2639	0.02466
Kurtosis	7.0169	18.5398	26.7145	12.2469	5.5829	4.8921
ADF	18.9576 ***	34.8010 ***	34.6221 ***	39.3132 ***	37.1135 ***	36.6162 ***
Jarque–Bera	914.3 ***	14325.3 ***	32303.9 ***	4895.3 ***	393.8 ***	203.0 ***
PP	-211.4574 ***	-34.8010 ***	-34.7744 ***	-39.3844 ***	-37.1159 ***	-36.6212 ***

3. Empirical results

3.1. Analysis of static spillover effects of the carbon market and the energy market

According to the static spillover analysis results in Table 2, it can be seen that the spillover index and spillover index between the carbon market and the energy market are both greater than 0, and the total spillover index is also greater than 0, which indicates China's carbon market. There is a volatility spillover with the energy market. The diagonal values represent the degree to which the lagging effect of the market affects the market, with internal effects greater than 65% for all variables. Among them, the internal impact of China's carbon market is 95.7%, indicating that China's carbon market has a strong autocorrelation. From the perspective of the overall spillover level of variables in China's carbon market and energy market, the average volatility spillover index of the market is 15.9%, showing strong linkage between markets.

Table 2: Static spillover index between carbon and energy markets

	CARBON	COAL	BRENT	GAS	LPG	NER	FROM
CARBON	95.7	0.6	1.0	0.9	1.0	0.9	4.3
COAL	1.2	91.2	2.1	1.7	2.2	1.5	8.8
BRENT	1.6	1.8	91.3	1.4	1.8	2.0	8.7
GAS	0.8	1.6	1.2	94.5	0.9	1.0	5.5
LPG	0.8	1.0	1.4	0.7	65.8	30.3	34.2
NER	0.6	0.8	1.4	0.8	30.4	66.0	34.0
TO	5.1	5.8	7.2	5.5	36.3	35.6	15.9
NET	0.8	-2.9	-1.5	0	2.1	1.6	

For China's carbon emission trading market, the volatility spillover effect between the carbon market and the energy market is two-way, and there are certain differences in the net spillover relationship between the carbon market and the energy market. The spillover intensity received by the carbon market from the energy market (coal 0.6%, crude oil 1.0%) is less than its output to traditional energy sources (coal 1.2%, crude oil 1.6%) the level of spillovers in the market; The level of spillovers received by the carbon market from the clean energy (0.9% LNG and 1.0% natural gas) markets is greater than its output to these markets (0.8% of LNG and natural gas). 0.8%). This also

shows that changes in China's carbon emission trading prices have a strong impact on traditional energy markets such as crude oil and coal. The carbon market and the clean energy market are the net exporters of volatility spillovers, while the coal market and the crude oil market are. The net receiver of the volatility spillover.

3.2. Analysis of dynamic spillover effects of the carbon market and the energy market

3.2.1. Analysis of total inter-market spillovers

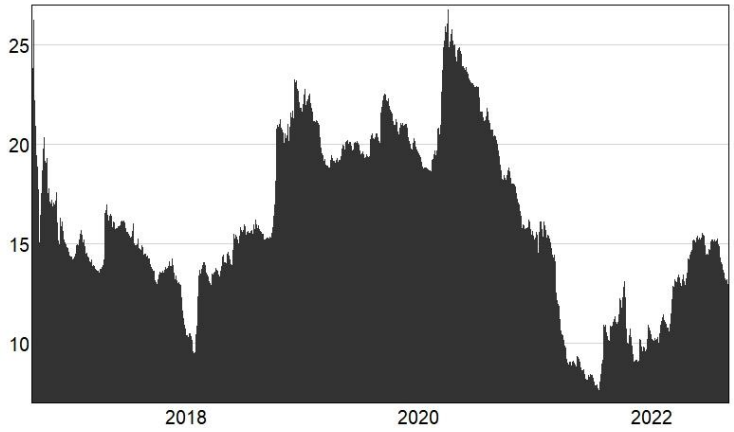

Figure 1: Total spillover index of carbon and energy markets

The total spillover index is used to measure the total amount of spillover of all variables in the system, and the level of linkage of the whole system can be evaluated through the total spillover index. Figure 2 shows the total spillover index of carbon market and energy market volatility. From the results of the index changes shown in the figure, it can be seen that the total spillover effect index of the carbon market and the energy market has large fluctuations from 2016 to 2022There is an obvious positive spillover effect with the energy market, and the total spillover effect is roughly 8%-25%. At different stages, there is a big difference in the size of the total spillover effect index between the carbon market and the energy market, showing significant time-varying characteristics. According to several periodic fluctuations of the total spillover effect, it can be found that the total spillover level between China's carbon market and the energy market shows a significant upward trend during the period of severe energy market shock, and the volatility spillover index is more sensitive to extreme events.

3.2.2. Analysis of directional spillover effect and net spillover effect between markets

The directional spillover index is used to measure the spillover relationship between a certain variable and all the other variables, and is divided into giving spillover and receiving spillover.

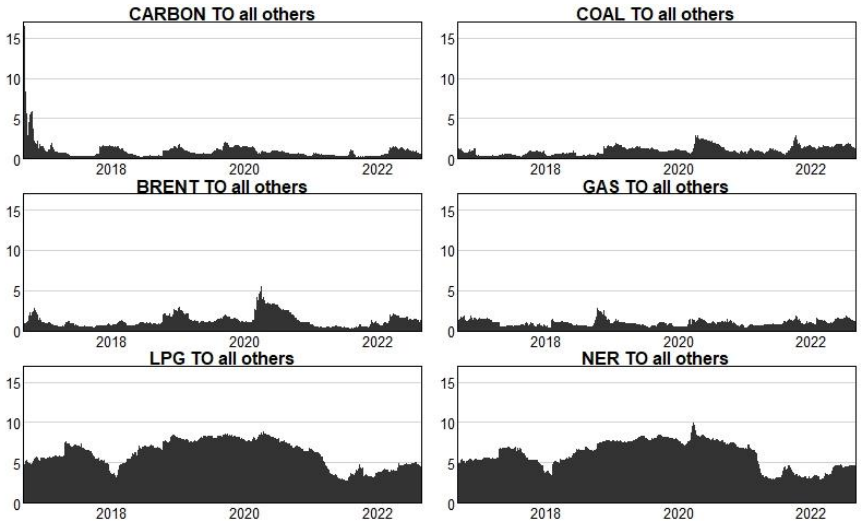

Figure 2: Directional spillover index between carbon and energy market returns

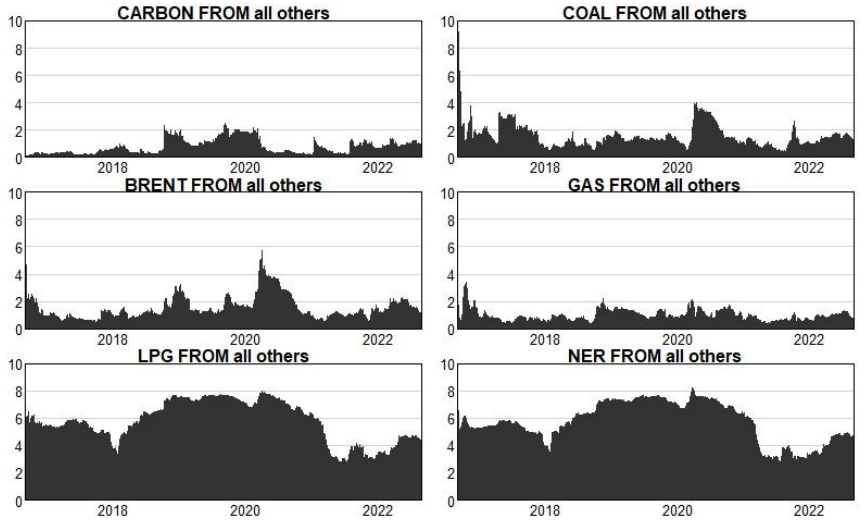

Figure 3: Directional spillover index between carbon and energy market returns

Figures 2 and 3 report on the risks of the carbon market, coal, crude oil, natural gas, liquefied gas, and new energy markets to the rest of the systemThe characteristics of the spillover effect and the risk spillover effect received from other markets over time. Figure 3 (**TO all others) shows the dynamic spillover effects of fluctuations in the carbon market or an energy market on five other variables in the system; FIGURE 4 (**FROM ALL OTHERS) SHOWS THE CARBON MARKET OR AN ENERGY MARKET RECEIVING FIVE OTHER VARIABLES IN THE SYSTEMDynamic spillover effects of fluctuations. It is clear from the acceptance and giving spillover indices in the graph that the spillover effect between the carbon market and the energy market is bidirectional and asymmetric. First of all, whether it is the carbon market or the energy market, there is a big difference between the level of spillover effect and the level of spillover effect, compared with other energy markets, we can see that whether it is to give spillovers to other markets or receive spillovers from other markets, the spillover indices of the liquefied gas market and the new energy index fluctuate most frequently. This reflects the relatively sensitive and relatively unstable characteristics of the clean energy market, which may be related to the late development of China's liquefied gas and new energy markets, which are slightly less mature than the traditional fossil fuel market.

Comparing the spillover and spillover index, it can be found that in the early stage of the

establishment of the carbon market, the spillover effect of the carbon market on the energy market is strong and unstable, and the spillover from the energy market is small in the carbon market, indicating that the risk fluctuation is mainly caused by the carbon market. Infected to the energy market, and then with the continuous development and improvement of China's carbon market construction, the spillover effect of the carbon market on the energy market gradually tends to stabilize, the spillover index fluctuates slightly within a certain range, and the carbon market receives an increase in the spillover index from the energy market. The spillover effect of the carbon market is gradually emerging, and the risk transmission of information transmission between markets is gradually stable.

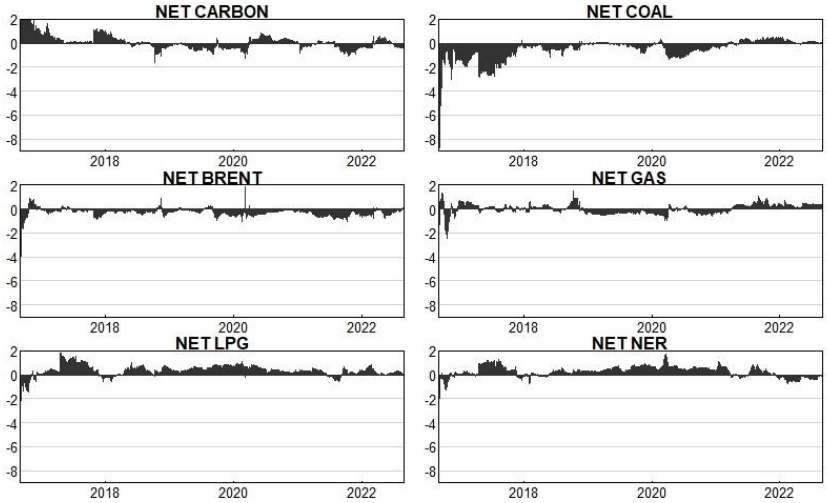

Figure 4: Net spillover index between carbon and energy market returns

As can be seen from Figure 4, the net spillover index of the energy market income of the carbon market shows that the net spillover index of the liquefied gas and new energy indices is positive overall in the selected sample interval, indicating that the spillover effect received by these two markets from other markets is less than the spillover effect they give to other markets, which are in the carbon market and energy market systems for a long time as an exporter of information risk spillovers. However, the net spillover index of coal and crude oil is mostly negative, and the overall performance is a net spillover effect, in which in early 2020, due to the global crisis of the new crown epidemic, many countries stopped work and production, global crude oil demand plummeted, and the price war between the United States and Tsarist Russia caused international oil prices to fluctuate sharply, resulting in the crude oil market in 2020. The annual spillover index is significantly different from usual, showing a high spillover effect, and most of the time the coal market and the crude oil market act as receivers in the risk transmission between markets, absorbing spillovers from changes in other markets. The net spillover indices of the carbon market and the natural gas market are positive and negative alternately and evenly distributed during the sample period, reflecting the carbon marketand spillover effects in the natural gas market are diverse over time.

4. Conclusions and Recommendations

By drawing on the improved DY spillover index model, the period from September 1, 2015 to September 2022 was selected. The price data of China's carbon market and energy market on January 1 systematically analyzed the yield spillover between the carbon market and the energy market, and the empirical results show that: There are significant cross market information linkages and price dynamic spillovers between China's carbon market and the energy market. There are significant differences and time-varying characteristics of spillover effects between different energy markets and carbon markets, and special periods and events of the economy and society will also have a great

impact on the degree of spillover effects. From the perspective of the static spillover index, the impact of emission trading price changes in China's carbon market on traditional energy markets such as crude oil and coal is stronger, and the impact on energy sources such as natural gas, liquefied gas and new energy is weaker. The coal market and the crude oil market are the receivers of volatility spillovers. From the results of dynamic spillover, it is found that in the early stage of the establishment of the carbon market, the spillover effect of the carbon market is strong, the spillover effect is weak, and the risk fluctuation of the carbon market is easy to be transmitted to the energy market. The spillover effect of the energy market on the carbon market is gradually emerging, and the spillover effect between the carbon market and the energy market is gradually stabilizing.

First of all, the state should use policies to guide the market. The carbon market is at the forefront, with a focus on stabilizing market prices and aligning environmental issues with the country's economic and social development goals. Governments should assume the role of policy guidance, administrative services and market regulation to mitigate and control the risks associated with the carbon market. For policymakers, it is necessary to take into account the interoperability between markets when designing relevant policies, that is, when issuing relevant policies for low carbon energy transition, it is necessary to take into account the impact of the policy on multiple markets such as carbon market and energy, strengthen the design of top-level mechanisms, and improve the effectiveness of legislation. Second, it is necessary to strengthen market operation, supervision, and law enforcement.

References

[1] Zhou Hongchun. Development and inspiration of the world carbon trading market[J]. China Soft Science, 2009, (12): 39-48.

[2] ZHANG Xiliang,ZHANG Da,YU Runxin. Theory and practice of national carbon market design with Chinese characteristics[J]. Management World,2021,37(08):80-95.DOI:10.19744/j.cnki.11-1235/f.2021.0108.

[3] Wu XL. Energy price, environmental protection technology and ecological environment quality-an analysis based on the DSGE model including carbon emissions[J]. Soft Science,2017,31(07):116-120.DOI:10.13956/j.ss.1001-8409. 2017. 07.25.

[4] WANG Zhonghua,HU Yao. Analysis of Influencing Factors of Carbon Emission Right Trading Price in China[J]. Industrial Technology Economy,2018,37(02):128-136.

[5] Ouyang Gelaoxin. Analysis of Influencing Factors of Carbon Emission Right Trading Price[J]. Times Finance, 2017(09):284-285.

[6] ZHANG Yuejun,WEI Yiming. Empirical Study on the Dynamic Impact of Fossil Energy Market on International Carbon Market[J]. Management Review,2010,22(06):34-41.

[7] ZHAO Yihang,ZHAO Huiru. Study on the spillover effect between China's carbon market and fossil energy market--an analysis based on VAR-GARCH-BEKK model[J]. Industrial Technology and Economics,2024,43(04):36-45.

[8] LIU Jianhe,WEN Congle,LIANG Jiali. Study on the spillover effects of carbon and energy markets in the context of trade war[J]. Industrial Technology and Economics,2021,40(07):57-64.

[9] ZHAO Lingdi, FAN Chao, WANG Haixia. Time-varying spillover effects between China's carbon market and energy market: An empirical study based on spillover index model[J]. Journal of Beijing Institute of Technology (Social Science Edition),2021,23(01):28-40.DOI:10.15918/j.jbitss1009-3370.2021.4972.

[10] Wang X-P,Wang T-T,Wang W-C. Research on risk spillover effect between China's carbon market and energy market based on spillover index method[J]. Electric Power Science and Engineering,2023,39(03):25-33.

[11] WANG Xi-Ping,WANG Wan-Chen. Study on risk spillover effect between China's carbon market and power market--Based on BK spillover index model[J]. Industrial Technology and Economics,2022,41(05):53-62.

[12] Khediri B K ,Charfeddine L .Evolving efficiency of spot and futures energy markets: a rolling sample approach[J]. Experimental Finance,2015,67-79.