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The Time-varying Co-movements between China's Regional Carbon Market

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Abstract

China's carbon emission trading market is still in the construction stage, and the market mechanism is not perfect. It is necessary to systematically analyze the risk spillover effect between China's pilot carbon markets. Based on the spillover index model, using the closing price of the carbon market from April 1, 2014 to March 23, 2021, the static volatility spillover index and the time-varying volatility spillover index among various carbon markets in China are depicted. The results show that there are two-way spillover effects among various carbon markets in China, and there are differences in the characteristics of the spillover effects and the net spillover relationship among carbon markets in different regions. The dynamic spillover index shows obvious time-varying characteristics, and the total spillover level between markets is mainly affected by the international environment.

Keywords

Carbon Market; Time-varying Overflow; Spill Index Model.

1. Introduction

In recent years, the climate issue has always been a key social issue of common concern around the world. Countries have reached a consensus on actively responding to climate change and jointly exploring a low-carbon development path. As the country with the highest carbon emissions, China has been committed to energy conservation and emission reduction, and hopes to achieve low-carbon green development as soon as possible. The carbon emissions trading market is to deal with climate change and reduce greenhouse gas emissions through market mechanisms. The establishment of a carbon emission trading market in my country can not only deal with climate change, but also solve environmental problems and build a beautiful China. Since 2013, China has established eight carbon emission trading markets. Under the background that China's carbon emission trading market is gradually maturing, by studying the volatility spillover effect of China's carbon market, it is possible to fully understand the process of information transmission between markets and establish a corresponding risk early warning mechanism, which is not only conducive to the improvement of the carbon trading market. Development is also conducive to the realization of low-carbon green development. This paper mainly starts from the global carbon market environment, focuses on the development history and reality of China's carbon market, and discusses the necessity and positive significance of the research on the spillover effect of China's regional carbon market. By studying the spillover effect of the carbon market, it is possible to understand the information transmission mechanism between carbon markets and the causes of carbon price fluctuations, so as to improve the risk management and control capabilities of the carbon market.

Regarding the research on the spillover effect of the carbon market, because the foreign carbon market was established earlier, compared with the Chinese carbon market, the development is more mature. The EU carbon emission system is the first carbon market in the world and the carbon market with the largest trading volume in the world. It has the most mature development among the global carbon markets. The research and analysis of the EU carbon market is of great significance to the construction of a national unified carbon trading system in my country. important reference. Reboredo proposed the volatility spillover effect of the EU carbon emission market and the EU oil market and showed that there was a volatility spillover effect between the two markets [1]. Liu & Chen (2013) based on the VAR-GARCH-BEKK model and hedge effectiveness value (HE) proposed that carbon futures and carbon spot markets have a high correlation and a two-way dynamic spillover relationship [2]. Benz et al. (2009) and Daskalakis et al. (2009) both took the EU carbon market as the research object, and found that carbon price yields have sharp peaks, thick tails and fluctuating aggregation characteristics [3][4]. Chevallier (2011) took BlueNext spot price and ECX futures price as research objects, and used nonparametric model analysis to show that carbon prices have asymmetry and heteroscedasticity [5]. Fan et al. (2015) used different indicators to study the EU carbon market, showing that the EU carbon market has fractal and chaotic characteristics [6]. Kanamura and Takashi (2016) found that there is a leverage effect on carbon prices in EUA and CER markets [7].

Based on the above related literatures, it can be found that due to the late establishment of China's carbon trading market, scholars' research on the carbon market mainly focuses on the EU carbon market, and there are few studies on the Chinese carbon trading market. This paper uses the spillover index method proposed by Diebold and Yilmaz (2012) to measure the spillover effect of volatility among China's carbon markets.

2. Method

By sorting out the current research results of scholars, the methods used in the research on carbon market spillovers mainly include VAR model and GARCH model (for example, GARCHBEKK, DCC-MGARCH). At present, GARCH-type models have two defects: one is that GARCH-type models cannot measure the size of spillover effects; the other is that a large number of parameters need to be estimated when using GARCH models, which is complicated to calculate and takes a long time. In addition, GARCH-type models cannot analyze dynamic spillover effects and cannot reflect the time-varying spillover relationship between variables. Diebold and Yilmaz (2012) improved the DY spillover index model in 2012[8]. The improved DY spillover index model mainly measures the empirical results in two different ways: static spillover index table and dynamic spillover index chart, showing fluctuations between different markets. The dynamics of the conduction mechanism. The specific process of this method is as follows:

Firstly, construct a stationary N-variable P-order vector autoregressive model (VAR) model; under the above vector autoregressive model framework, the improved DY spillover index model adopts the model proposed by Koop et al. [9], Pesaran and Shin [10]. The KPPS method (Generalized Variance Decomposition) deals with the impact of the forecast residual term, and finally defines the spillover index. The total spillover index is used to measure the overall correlation between different markets. It uses the KPSS variance decomposition method to measure the contribution of information spillovers between all variables in the model to the total forecast residuals of the model. Directional overflow index. The directional spillover index can measure the size of the spillover effect of market i on all other markets j, and the size of the spillover effect of all other markets j received by market i. The net spillover index measures the net spillover of a single market to all other markets. The net spillover index is derived from the shocks transmitted from market i to all other markets minus the total shocks transmitted from other markets to market i. If there are multiple (more than two) markets under analysis, the net paired spillover index can be used to measure the volatility spillover effect between the different two markets.

The overflow index is divided into static overflow index and dynamic overflow index. The static overflow index is analyzed for all samples, and the full-sample overflow index is obtained. The dynamic spillover index combines the rolling window technique to fit the samples in sections to study the fluctuation spillover effect at different time points, and obtain the time-varying spillover index sequence. The static spillover index can be represented by the spillover index table, and the dynamic spillover index can be represented by the time series chart of spillover effect intensity.

3. Empirical Analysis

3.1. Data Sources and Descriptive Statistics

In December 2017, China's carbon emissions trading market was established, and nine regional carbon trading markets have been established so far. Each carbon market was established at a different time, and the market activity and liquidity were also different. The Sichuan carbon trading market was established in July 2021 and is not a carbon emissions trading market for this article. The data of carbon market in different regions come from the carbon K-line website.

According to Figure 1, among the eight carbon markets, the Hubei carbon market accounted for the highest trading volume at 29.41%. Although the Hubei carbon market was established late, its trading volume ranks first. The second is the Guangdong carbon market, the Shenzhen carbon market, and the Shanghai carbon market. The total trading volume of the three carbon markets is close to half of the total trading volume. Among the eight carbon markets, Chongqing, Fujian, and Tianjin have relatively few carbon markets. As the carbon market in the non-pilot region of the country, the Fujian carbon market was established relatively late, and it is difficult to maintain data consistency with other carbon markets. At the same time, the carbon price data of the Chongqing carbon market is seriously lacking. Therefore, this paper selects the six representative carbon markets of Shanghai, Beijing, Guangdong, Shenzhen, Tianjin and Hubei as the research objects. These carbon markets were created earlier and are well-documented.

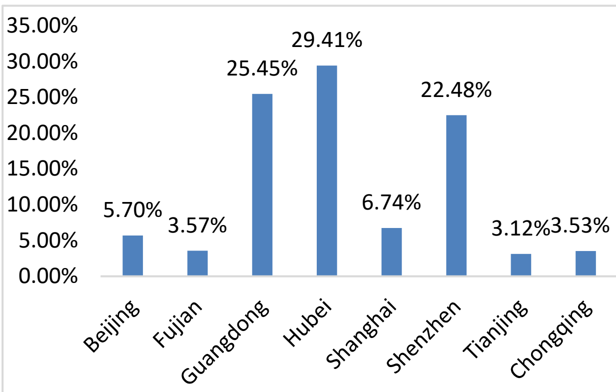

Figure 1. 2014-2020, distribution of carbon market trading volume by region

The sample interval of carbon market indicator data starts from April 1, 2014, ends on March 23, 2021, and takes the daily closing price of the carbon market as the negotiated price. To ensure the stationarity of the data, the first-difference form of the variables is chosen. Table 1 presents the descriptive statistics of the volatility of six carbon emission trading prices. It can be seen from Table 1: the Jarque-Bera statistic rejects the null hypothesis at the 1% significance level, proving that each variable obeys the non-normality state distribution. The ADF test results show that each variable is stationary, so the DY spillover exponential model can be applied to the selected data.

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Table 1. Descriptive statistics for each sequence

statistical magnitude	Regional carbon market					
	Beijing	Guangdong	Hubei	Shanghai	Shenzhen	Tianjing
Mean	59.38	23.52	23.76	31.41	35.79	18.53
Median	53.15	19.11	24.50	35.30	35.15	16.75
Maximum	151.35	77.00	54.42	71.64	93.50	50.18
Minimum	25.00	8.10	10.07	4.20	7.16	7.00
Std.Deviation	16.38	13.37	6.40	11.89	15.05	7.15
Skewness	0.76	1.96	0.37	-0.79	0.80	0.47
Kurtosis	2.94	6.77	3.91	2.72	4.63	2.69
J-B	179.81	2277.71	105.91	195.65	401.62	73.99
ADF	-40.54	-39.73	-22.42	-18.42	-35.47	-32.79

3.2. Static Overflow Index

The static volatility spillover effect among six carbon markets in China is analyzed by constructing a static volatility spillover index table. In this paper, the lag order of the VAR model of each series is set to order 2, and the prediction error step H is set to 10 days with reference to Diebold and Yilmaz (2012). Table 2 is a table of volatility spillover indices among China's Shanghai carbon market, Beijing carbon market, Guangdong carbon market, Shenzhen carbon market, Tianjin carbon market and Hubei carbon market. The elements on the diagonal line in Table 2 represent the contribution of the prediction variance from the variable itself, and the elements on the off-diagonal line represent the contribution of the prediction variance from other variables, that is, the spillover effect. The values in the last column of Table 2 represent the spillover effects of all other variables on a variable; the values in the third-to-last row represent the spillover effects of a variable on all other variables; the values in the last row represent the net spillover effects of a variable.

Each spillover index in the static spillover index table is not 0, indicating that there are volatility spillovers among the six major carbon markets in China. The values on the diagonal line indicate that the price changes in the six carbon markets contribute mainly to the variance themselves. The spillover effect and spillover effect between the Hubei carbon market are obvious, and the mutual spillover effect between the Hubei carbon market and the Guangdong carbon market is more obvious, and the two show a relationship of mutual fluctuation and spillover. From the net spillover index, Shenzhen carbon market and Guangdong carbon market are net exporters of volatility, and other carbon markets are net importers of volatility.

Table 2. Static Overflow Index Table

	Beijing	Guangdong	Hubei	Shanghai	Shenzhen	Tianjing	From others
Beijing	98.71	0.04	0.10	0.56	0.59	0.00	1.29
Guangdong	0.00	96.24	2.20	0.43	0.36	0.77	3.76
Hubei	0.11	3.13	96.13	0.03	0.34	0.26	3.87
Shanghai	0.22	0.61	0.07	98.37	0.01	0.73	1.63
Shenzhen	0.01	0.33	0.05	0.23	99.38	0.01	0.62
Tianjing	0.09	0.95	0.41	0.34	0.39	97.82	2.18
Directional TO Others	0.43	5.05	2.82	1.59	1.69	1.77	13.35
Directional Inlcuding Own	99.13	101.29	98.96	99.96	101.07	99.60	0.02
NET	-0.87	1.29	-1.04	-0.04	1.07	-0.40	2.22

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3.3. Dynamic Overflow Index

Static volatility spillover tables alone do not adequately capture dynamic spillovers over time, which can miss important information. This paper refers to Diebold and Yilmaz to combine the rolling window technique with the DY overflow index method to measure the dynamic change of the overflow index.

3.3.1. Total Spillover Effects between Carbon Markets

Figure 2 shows the total spillover index of China's carbon volatility system, respectively. Firstly, by analyzing the changes of the total volatility spillover index, it can be found that the total volatility spillover index between carbon markets has fluctuated greatly in the past few years, and the total volatility spillover of the carbon market has shown significant time-varying characteristics during the investigation period. Second, the graph of the total spillover index exhibits some notable features of variation. The first period is from 2014 to 2017, and the total spillover index shows the characteristics of volatility. The total spillover index rises in stages within a certain range and then declines. Among them, from the end of 2015 to the middle of 2016, the total spillover index was on the rise. In order to promote the optimization of the energy structure, China proposed energy supply-side reforms at the end of 2015, especially in early 2016, the coal industry began to carry out structural adjustments, which led to violent fluctuations in the prices of coal industry products during the period, and the fluctuations spilled over to other countries. The carbon market, so that the total spillover index between markets rises rapidly. At the end of 2015, due to the influence of OPEC policy changes and risk transmission, the total spillover index between carbon markets was in a stage of gradual decline. The second period is from September 2018 to 2021. During this period, the total spillover index showed a continuous and substantial increase, mainly due to the Sino-US trade friction, China's import and export of resources was affected, and the carbon market was inevitably affected. In response to the impact of changes in the economic environment, the spillover effect between carbon markets has become stronger.

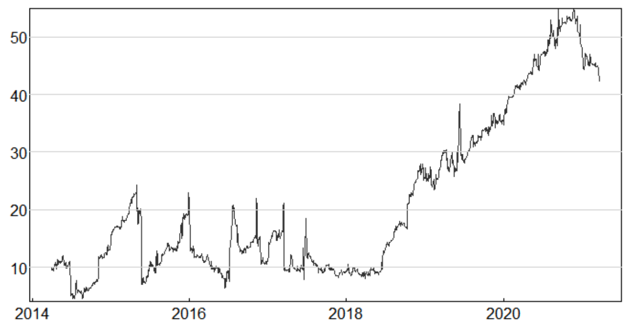

Figure 2. China Carbon Market Total Spillover Index

3.3.2. Directional Spillover Effect between Carbon Markets

This paper further analyzes the directional spillover effects and net spillover effects between carbon markets in various regions. The directional spillover effect between carbon markets is also significantly time-varying. In addition, from the directional spillover index chart, we can see that the time-varying spillover effects between carbon markets in different regions of China are bidirectional and asymmetric. The directional spillover indices of the six carbon markets all showed a rapid rise after 2018. Among them, the directional spillover effects of the Hubei carbon market and the Guangdong carbon market were obvious for a long time in the sample period, showing a wave-like change. Figure 4 is a graph of the net spillover index between carbon markets. It can be seen that, different from the static net spillover relationship, the time-varying net spillover relationship among China’s carbon markets does not always remain positive or negative, that is, there is not only a unidirectional net spillover between carbon markets, but both. net spillage in different directions.

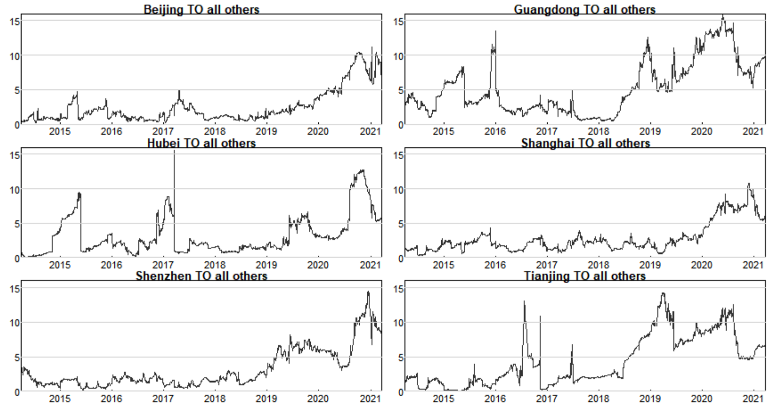

Figure 3. Directional spillover effects between carbon markets

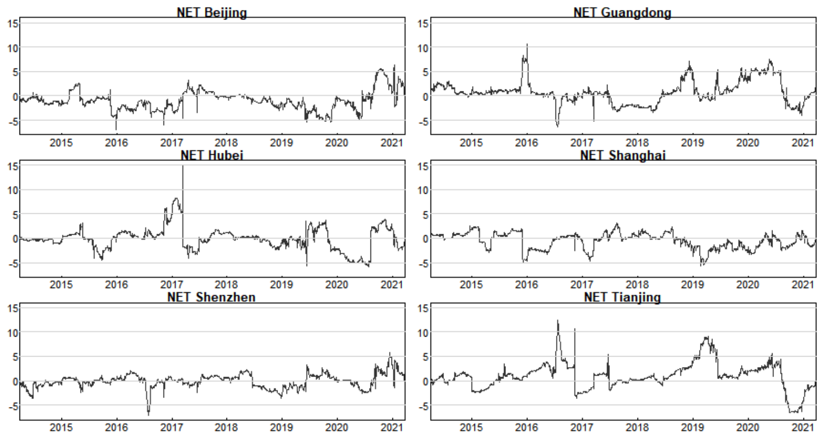

Figure 4. Net spillover effect between carbon markets

4. Conclusion

Based on the DY spillover index model, this paper makes a systematic analysis of the spillover effect between China's carbon markets. According to the calculation results of the cross-market spillover index in the empirical part, the following conclusions are drawn: First, the calculation results based on the full sample show that there are two-way volatility spillovers between carbon markets, but the characteristics of spillover effects and the net spillover relationship between different carbon markets are different. In terms of spillover characteristics, the spillover effect and spillover effect between Hubei carbon markets are obvious, and the mutual spillover effect between Hubei carbon market and Guangdong carbon market is more obvious, and the two show a relationship of mutual fluctuation and spillover. In terms of the net spillover relationship, the Shenzhen carbon market and the Guangdong carbon market are net exporters of volatility, and other carbon markets are net importers of volatility. Second, the calculation results based on the rolling window show that the volatility spillovers between China's carbon markets have significant time-varying characteristics. The inter-market total spillover index and the directional spillover index show strong time variability in both the spillover size and the spillover direction. The time-varying size and direction of spillover effects show that China's carbon market will be impacted by relevant external markets and affected by changes in the international environment, and the information transmission mechanism between carbon markets has great uncertainty.

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