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Spillover Analysis of Carbon Market, Crude Oil Market, and Coal Market based on BEKK-GARCH

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Abstract. Global warming has become an urgent issue for all mankind, and climate change caused by carbon dioxide emissions is a growing concern. China, as a major global energy consumer, has set "carbon neutrality" as its vision for 2035. This study aims to explore the impact of carbon neutral policy on the volatility of the energy market, and through a comprehensive analysis of the historical data of the carbon market, crude oil market, and power coal market returns, we aim to reveal the volatility spillover effect among markets. In this study, we determine the distribution trend of yield receipts as t-distribution by performing statistical tests, ADF analysis on the yield historical data of the three markets. Under this premise, ARCH model, GARCH model and EGARCH model are further used to carry out the preliminary validation of the yield series of each market, and under the premise of ensuring the existence of volatility benefits in the data of each market, BEKK-GARCH model is used to carry out the analysis of multi-market spillover benefits, and the significance of the results is ensured by the WALD test. Finally, the results of the study are linked to actual policies and market operations to provide relevant recommendations for governments, investors, enterprises and carbon trading platforms. This study provides in-depth market perspectives and policy support for addressing the challenge of climate warming, and provides strong data support and decision-making reference for achieving the goal of carbon neutrality.

Keywords: BEKK-GARCH; Market Spillover; Arch1 Introduction.

1. Introduction

1.1. Background

To date, 34 carbon emissions trading systems have been put into operation at all levels of government around the world, covering 17 per cent of total global greenhouse gas emissions. China has also launched a national-level carbon emissions trading market. Since carbon dioxide emission rights have become a tradable commodity, with the growth and expansion of the carbon market, emission rights have been regarded as a financial asset that can participate in investors' asset allocation.

From the various research results carried out by scholars at home and abroad, it can be seen that there exists a certain link between the carbon emissions trading market and the energy market, and the markets can influence each other. The study of this influence will become more and more important with the development and improvement of the carbon market mechanism.

1.2. Research Innovation

There are a large number of innovations in the research of this paper, which can be summarised as shown below:

1. Due to the late start of China's carbon emissions trading market, most scholars are based on the study of the European carbon market, followed by the development of China's carbon market for macro guidance. There are fewer studies on China's carbon market. This paper is based on the perspective of China's carbon market, and at the same time selects China's power coal options market to study the interactions between China's carbon market and the energy market.

2. Most of the current literature will choose a model that takes into account the different proportions of the use of coal, oil and natural gas, and discusses the coal market and crude oil market with the carbon market by establishing GARCH and BEKK-GARCH models respectively, and enriching the portrayal of the asymmetric volatility by using the two models, EGARCH and BEKK-GARCH.

2. Assumption

1. It is assumed that price volatility exists in the data of multiple markets studied in this paper, and this volatility can be captured from the time series (ARCH, GARCH, EGARCH, BEKK-GARCH models).

2. it is assumed that in the markets studied in this paper, multiple markets may be in mutual shocks, and the shocks may have the same or asymmetry.

3.Assume that in this paper, the data is accurate after the data is detected by preprocessing and there is no abnormal data.

3. Symbols

The following table describes the symbols.

Table 1. Symbols and significance

Symbol	Meaning
P_t	Market price at day t
R_t	The rate of return at day t
u_t	The random error term (disturbance term) in the sequence of returns at time t
σ_t^2	Conditional variance of ut
h_{11t}	Conditional variance of market 1 returns
h_{22t}	Conditional variance of market 2 returns
a_{11}	Impact of shocks in the previous moment of market 1 on current volatility
b_{11}	Impact of Market 1 previous moment volatility on current volatility

4. Empirical Analysis of Multi-market Spillover Benefits

4.1. ARCH, GARCH, EGARCH Benefit Tests for Multiple Markets

In this paper, the data between 4 January 2016 and 5 December 2022 are selected as samples, in which the carbon market and crude oil data are from flush ifind, and the crude oil market data and coal market data are from the wind financial database.

Based on this, we will further logarithmise the closing price data of each market to obtain the serial representation of the return as

$$R_i = \ln(\frac{P_t}{P_{t-1}}) \quad (1)$$

Based on the above data processing, it is possible to analyse the markets using their rate of return data to determine whether there are spillover benefits between the various markets. After completing the data pre-processing, we empirically analysed the spillover effects between the carbon, crude oil and diesel markets. Using python software, the time series of yields representing the three markets were empirically investigated, and the statistical rows describe the results as shown in the table below:

Table 2. Descriptive Statistical Analyses by Markets

Variable	Carbon market	Dynamic Coal Market	Crude oil market
Obs	1820	1820	1820
Mean	0.000510	0.000895	0.000458
Std	0.022234	0.036724	0.026760
Min	-0.210329	-0.363348	-0.308539
Max	0.315236	0.361097	0.154499
JB	82637.377482	22627.289591	34530.977419
P	0.000000	0.000000	0.000000

Analysing the above results in terms of standard deviation, the standard deviation of the carbon market is 0.022234, the power coal market is 0.036724 and the crude oil market is 0.026760.This indicates that the power coal market has the highest volatility while the carbon market has the lowest volatility.

As the yield time series have ARCH effect, it indicates that carbon market, power coal market and crude oil market all have certain volatility agglomeration effect, i.e., the EGARCH model is valid.

In order to investigate whether there is any difference in the impact of the rise and fall of the yield on the possible future volatility, this paper chooses the EGARCH model to explain the existence of the "leverage effect". The EGARCH model analyses the relationship between the carbon market, the coal market and the crude oil market, and explores whether there is an asymmetric interaction between the carbon market and the remaining two markets.

Table 3. EGARCH model analysis by market

Variables	Carbon Markets			Power Coal Market			Crude Oil Market		
Parameters	Estimate	t	p	Estimate	t	p	Estimate	t	p
omega	-1.37877	-3.091	1.99e-3	-0.05	-0.554	0.580	-0.243	-3.005	2.656e-03
alpha[1]	0.528184	10.0	1.0e-23	0.289	1.455	0.146	0.225	4.975	6.570e-07
gamma[1]	0.052828	1.352	0.176	-0.04	-0.531	0.595	-0.079	-2.897	3.763e-03
beta[1]	0.784451	11.562	6.4e-31	0.990	65.905	0.000	0.9665	89.351	0.000

From the results in the table, it can be concluded that there is no asymmetric effect in the carbon market and the power coal market, and the impacts of negative news and positive news of the same size on the market are roughly the same; while there is an asymmetric effect in the crude oil market represented by WTI, with a gamma of -0.07908, i.e., negative news of the same size has a more pronounced impact on the market.

The WTI futures market has developed over a long period of time, the market is more mature, and there are more investors in the market, so the market reflects more adequate information, including not only profit forecasts of the options themselves, but also the management of the company, and at the same time, it will be affected by the policy and geopolitics, and the investors will react to this information quickly, so the information has a more obvious impact on the WTI.

4.2. Carbon, Crude Oil, and Power Coal Market Spillover Benefit Tests

The BEKK-GARCH model is able to respond to a certain extent to the market see volatility of the selected samples and the transmission of risk[1].

In this paper, the BEKK-GARCH model is used to model the daily return series of China's carbon market price and power coal market price and carbon market price and crude oil market price to explore the direction and intensity of volatility spillovers between the two groups of markets[2]. beckk-GARCH model results obtained are shown below

Table 4. Analysis of Spillover Benefits from Carbon and Power Coal Markets

Variables	Ratio	Standard error	T-value	P-value
C_{11}	0.001598372	0.000984085	1.62422	0.10432865
C_{21}	-0.000529396	0.006794565	-0.07791	0.93789595
C_{22}	0.002582184	0.001832870	1.40882	0.15888832
A_{11}	0.682336169	0.253699211	2.68955	0.00715489
A_{12}	-0.037834048	0.036581266	-1.03425	0.30102092
A_{21}	-0.023539723	0.033824167	-0.69594	0.48646396
A_{22}	4.329586621	1.520072225	2.84828	0.00439567
B_{11}	0.980578453	0.003274336	299.47402	0.00000000
B_{12}	0.003130144	0.004906351	0.93921	0.34762242
B_{21}	0.443349325	0.007300080	0.42878	0.66808182
B_{22}	2.085819135	0.018830142	23.54466	0.00000000

Table 5. Analysis of Carbon and Power Coal Market Assumptions

Original Hypothesis	Chi-Squared	P value
No volatility spillover from COAL to CARBON $A_{12} = B_{12} = 0$	1.565	0.457
No volatility spillover from CARBON to COAL $A_{21} = B_{21} = 0$	0.574	0.750
No volatility spillovers between the two $A_{12} = B_{12} = A_{21} = B_{21} = 0$	2.118	0.714

Table 6. Analysis of spillover benefits from carbon and crude oil markets

Variables	Ratio	Standard error	T-value	P-value
C_{11}	0.008643549	0.002414558	3.57977	0.00034390
C_{21}	0.000942888	0.001577031	0.59789	0.54991480
C_{22}	-0.002013904	0.001052377	-1.91367	0.05566201
A_{11}	0.623859697	0.160008650	3.89891	0.00009663
A_{12}	-0.017643985	0.015599112	-1.13109	0.25801763
A_{21}	0.089694451	0.051133090	1.75414	0.07940702
A_{22}	3.488060011	0.913579769	3.81801	0.00013453
B_{11}	0.961059567	0.004922593	195.23443	0.00000000
B_{12}	-0.002222923	0.004706923	-0.47227	0.63673638
B_{21}	-0.027891967	0.009977470	-2.79550	0.00518203
B_{22}	0.445738630	0.019907502	22.39049	0.00000000

As can be seen from the data in the table, the P-value test results of the correlation coefficients between the carbon market and the power coal market are all insignificant, indicating that there is no volatility spillover effect between the returns in the carbon market and the returns in the power coal market [3]

Table 7. Analysis of carbon and crude oil market scenarios

Original Hypothesis	Chi-Squared	P-value
No volatility spillover from OIL to CARBON $A_{12} = B_{12} = 0$	1.893	0.388
No volatility spillover from CARBON to OIL $A_{21} = B_{21} = 0$	8.286	0.015
No volatility spillovers between the two $A_{12} = B_{12} = A_{21} = B_{21} = 0$	11.775	0.019

As can be seen from the data in the table, $B_{11}$and B_{22} are not zero at the 5% significance level, indicating that both carbon and crude oil markets have volatility agglomeration, which can also prove the existence of ARCH effects in the two markets; A_{11} andA_{22} are not zero at the 5% significance level, indicating that there are GARCH effects in the two markets, which is also in line with the experimental results of the previous article; A_{21} and B_{21} are not zero at the 5% significance The values of A_{11} and B_{11} are not zero at the 5% significance level, indicating that there is a one-way volatility spillover effect from the carbon market to the crude oil market at the 5% significance level; while $A_{21}$and B_{21} are not significant, indicating that there is no one-way volatility spillover effect from the crude oil market to the carbon market.

In general, the spillover effects of both the power coal market and the crude oil market on the carbon market are not significant, and the spillover effect of the carbon market on the power coal market is not significant, but the spillover effect of the carbon market on the crude oil market is more significant[4-5].

5. Conclusion

Based on the above research, this paper detects the volatility benefits of each market through ARCH model, GARCH model, and E-GARCH model for carbon market, crude oil market, and power coal market.

In addition, this paper analyses the spillover benefits among the three markets by constructing the Bekk-garch model, and finally obtains the conclusion that there is no volatility spillover effect of the carbon market on the coal market, and there is volatility spillover effect of the carbon market on the crude oil market.

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