Comparative Study on the Fluctuation of Carbon Emission Price in China

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Abstract: The carbon emissions trading is an internationally proven effective market-based instruments to control greenhouse gas emissions, which improves self-awareness of enterprises and individuals in reducing emissions through market trading methods and gradually reduces total social emissions. In the process of carbon trading, the financial attributes of carbon emission rights have gradually become prominent, mainly manifested by its "quasi-monetary" characteristics and the particularity and breadth of financial assets. Carbon emission rights as an emerging financial asset, we still do not have sufficient knowledge and understanding of the fluctuation characteristics and laws of its prices, so we cannot effectively understand the risks of carbon emission trading markets and build a better carbon market. Therefore, this paper uses the GARCH family model to study the fluctuation characteristics of the carbon emission rights price of eight carbon pilots in China, and gives policy suggestions for the construction of China's unified carbon emission market.

1. Introduction

The "Kyoto Protocol" issued in 1997 mandated the assignment of greenhouse gas emissions in developed countries. The huge pressure to reduce emissions prompted developed countries to establish carbon trading markets and purchase certified emission reductions from developing countries. Carbon trading has become an emerging hot issue in the world. The Paris Agreement, a global emission reduction agreement signed in 2015, included China in the list of mandatory emission reduction countries, and the development of the carbon trading market in China has become increasingly important.

Since 2011, China has taken the lead in launching carbon emissions trading pilots in Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong and Shenzhen. At the end of 2017, the construction of a unified national carbon market with a breakthrough in the power generation industry was officially launched and will be officially launched in 2020. After the transaction, seven other high-emission industries such as petrochemical, chemical, building materials, steel, nonferrous metals, papermaking and aviation will also be gradually included. The world's largest carbon market will be gradually established in China, which has more than 7,000 emission-controlling entities, and the total annual greenhouse gas emissions reached 4-5 billion tons. As the largest national carbon market in the world, the healthy development and good operation of the market have a profound impact on Chinese energy saving and emission reduction business.However, as a policy-built emerging market, compared with the EU mature trading system, Chinese carbon market is still underdeveloped. At this stage, the price of carbon trading fluctuated violently, which undoubtedly brought huge risks for the government and related companies to participate in carbon trading.

Due to differences in the spatial and geographic distance, regional economic development level, basic economic structure, industrial layout, energy consumption structure, market size, climatic conditions, and related policy formulations among the eight carbon emission pilots in China, there are large differences in China's pilot carbon markets.Many factors affecting trading make carbon prices fluctuate significantly, which is not conducive to guiding the carbon market to make reasonable resource allocation. Due to the lack of pricing mechanism, China is in a passive situation

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in the international carbon market. As the largest emitter of carbon dioxide, Chinese carbon trading market should comprehensively consider various factors that affect fluctuations and formulate corresponding policies and plans to ensure the stable operation of the carbon trading market. The innovation of this paper is mainly reflected in the overall analysis of Chinese carbon price fluctuation based on regional differences.

2. Literature Review

In a related study on the fluctuation characteristics of the price of carbon emissions rights in foreign countries, Daskalakis et al. (2009) found that the EU carbon emissions market price-return sequence used a model to verify that the sequence had “spike tails” conditional heteroscedasticity [1]. Zhang Yuejun and Wei Yiming (2011) used the GARCH model, VAR model, and mean regression theory to study the operating characteristics of the futures price of the EU carbon market. The results of the study showed that the fluctuation of the EU's carbon quota price yield rate did not obey the mean regression process [2]. A study by Palao and Pardo (2012) found that there is a relatively strong price agglomeration effect in the EU carbon emissions trading market, and as transaction costs increase, the phenomenon of volatility agglomeration becomes more significant [3]. Zhang Yujuan (2013) used the stochastic fluctuation model to study the fluctuation characteristics of the futures price of the EU carbon market, and found that the second stage of futures prices obeyed the mean regression process. The reason for this phenomenon is that the development of the EU carbon emissions futures market is relatively mature [4].

As China is in the early stages of the development of carbon emission markets, the different design of carbon emission market systems and policy adjustments will make carbon prices susceptible to fluctuations. Lu Yongbin used the GARCH family model research to find that the yield fluctuation of China's carbon emission trading has agglomeration characteristics, and the carbon price changes show regional differences [5]. DU Li (2015) by studying the species found ARCH model, the risk of carbon exchange of different pilot areas, the price impact of the decay rate, VaR statistical characteristics were significantly different than [6]. Guo Baixun (2 016) researched the carbon trading price level and its fluctuations and found that the carbon trading price in each pilot region of our country has seasonal characteristics, and the market activity can be increased by introducing institutional and individual investors, and the carbon trading price has Seasonal characteristics [7]. Wei Suhao (2016) used the R / S analysis method to test the non-linear characteristics and status of China's carbon price, and found that the trading risks in the pilot markets are different and there is no periodic cycle [8]. Xu Jia, Tan Xiujie (2 016) based on the integrated empirical modal decomposition (EEMD) method to decompose six carbon trading pilot prices with high carbon trading volume in China into several independent, different periods of IMF components and trend terms, and According to its high and low frequency reconstruction into the high frequency component, low frequency component and long-term trend term of the original price series, the spatial and temporal heterogeneity of the factors affecting the price fluctuations of the six carbon trading pilots is compared and analyzed. price volatility by factors of three different periods of short-term fluctuations, events and market internal mechanism of the market impact varies [9]. Xin Jiang, Chunyan Zhao (2018) analyzed the fluctuation characteristics of carbon emission trading market prices under different regional systems using the Markov system vector autoregressive regression model, and found that the impact of market prices is multi-dimensional and time-varying. Financial markets, Industrial markets, energy markets, and foreign carbon trading markets will all have an impact on their prices and are interrelated [10]. Zhang Jie, SUN red, Zhen Xing six pairs of Chinese carbon emissions trading market price volatility sequence study, found that the presence of these market volatility asymmetry characteristics, and proposed the development of national carbon emissions trading market suggested [11]. Li Feifei, Jiang Hao, and Xu Zhengsong (2019) selected weekly carbon trading price data of carbon emission pilot regions such as Beijing and Shanghai, used the GARCH family model to analyze and discuss carbon trading price fluctuations and risk characteristics in the pilot regions, and verified carbon price fluctuations at VaR Risk differences, put forward suggestions to increase the size of the carbon market, increase the activity of carbon trading, take feasible measures to monitor the fluctuation of carbon trading prices in various places, and effectively avoid trading risks [12].

3. Analysis on the construction of a theoretical model for price volatility in Chinese carbon trading market

3.1 Variables and data description

From the perspective of data availability, the average daily spot price of carbon allowances in eight carbon emission trading markets in China (expressed as the ratio of the transaction volume to the transaction volume) was selected as the analysis object. In order to more intuitively reflect the trading situation of the eight carbon emission trading markets, the carbon emission trading volume selected in the same time period is selected as the sample size. The sample time is from January 9, 2017 to November 22, 2019, and the sample start time is the first day of the open trading of the Fujian carbon emission market. In order to reduce the volatility characteristics of the price series, the rate of return sequence in the sample interval is calculated from the sample price, and the empirical analysis is performed on the rate of return.

The yield $R_{(t)}$ is expressed as the logarithmic yield of the average transaction price of the exchange: $R_{(t)}$=ln$P_{(t)}$-ln$P_{(t-1)}$.Among them, R (t) represents the rate of return at time t, and P(t) represents the price of carbon emissions at time t. Because the Shenzhen and Tianjin carbon trading markets have too few trading days throughout the study period, this article does not study their price fluctuation characteristics for the time being.

Table.1. Sample data selection and variable naming of China's carbon emissions trading market

Pilot	Carbon quota	Daily transaction price	rate of return	Sample size	Proportion of effective trading days%
Beijing	BEA	BEAPRICE	RBEA	402	57.51
Shanghai	SHEA	SHEAPRICE	RSHEA	440	62.86
Guangdong	GDEA	GDEAPRICE	RGDEA	648	92.18
Shenzhen	SZA-2013	SZA-2013PRICE	RSZA-2013	130	18.36
Hubei	HBEA	HBEAPRICE	RHBEA	700	100
Chongqing	CQEA	CQEAPRICE	RCQEA	343	49.07
Fujian	FJEA	FJEAPRICE	RFJEA	459	65.67
Tianjin	TJEA	TJEAPRICE	RTJEA	6	0.86

Data source: According to the data of China Carbon Trading Network

3.2 Fluctuation characteristics of carbon trading prices in pilot areas

The market activity is represented by the ratio of days with trading volume to total days. Table 1 shows, Hubei carbon quota effective trading day, the highest proportion, reaching 100%, cross easily the most active, followed by Guangdong, Shanghai, Fujian, Beijing, Chongqing, Shenzhen, least active of Tianjin. Hubei was the first to introduce individual and institutional investors, which played a role in promoting active carbon market transactions. Most of the companies that have incorporated carbon emissions in Tianjin are state-owned and state-owned enterprises. There is no effective constraint on whether companies enter the carbon market and whether they fulfill their contracts. Lighter, trading in the carbon market is in a downturn.

Price analysis results of the pilot carbon trading carbon credits are shown in Table 2 as shown in the pilot regions due to significant regional differences in the pilot areas, the carbon price is quite different. From the perspective of average carbon allowance price, Beijing has the highest average price of carbon allowances and Chongqing has the lowest average price. From the maximum and minimum values of carbon allowance prices, it can be seen that Shenzhen has the largest price difference, which is 43.74 yuan/ton. The smallest price difference is the Tianjin carbon quota (5.5 yuan/ton). From the standard deviation, the fluctuation range of the carbon quota price can be observed. It can be seen that the price fluctuation of the Beijing carbon quota is the largest (standard deviation is 15.34). Shenzhen, Hubei and Fujian also have large fluctuations in carbon prices, followed by Chongqing, Shanghai, and Guangzhou. Tianjin has the smallest fluctuations in carbon quotas (standard deviation is 1.97).

Table.2. Liu Jia carbon emissions trading market price statistical description

variable	Mean	Max	Min	Std.Dev	Skewness	Kurtosis	Jarque-Bera
BEAPRICE	62.65	87.50	58.50	15.34	0.34	1.91	27.66 ***(0.000001)
GDEAPRICE	17.19	27.47	9.8	4.39	0.76	2.27	76.97 (0.00000)
SZA2013PRICE	28.59	58.91	15.17	8.79	0.74	3.45	13.16 (0.0014)
HBEAPRICE	22.83	53.85	11.56	8.62	0.59	2.37	51.97 (0.0000)
CQEAPRICE	6.72	35.4	1.00	6.12	1.96	7.05	455.33 (0.0000)
FJEAPRICE	23.45	42.28	7.19	8.33	0.42	2.20	25.52 (0.000003)

Note: *** means passing the significance test at the level of 1% of the variable, ** means passing the significance test at the level of 5% of the variable, and * means passing the significance test at the level of 10% of the variable.

3.3 The choice of theoretical model

3.3.1 Construction of Fluctuation characteristics based on GARCH model

Through the fitting results of the GARCH model, it is possible to analyze the impact of external good news and negative news on the price of carbon emissions. The model has the form:

$$\sigma_t^2 = \omega + \sum_{j=1}^{q}\beta_j\sigma_{t-j}^2 + \sum_{i=1}^{p}\alpha_i\mu_{t-i}^2 = \alpha_0 + \alpha(L)\mu_t^2 + \beta(L)\sigma_t^2$$

Where p is the order of ARCH, q is the order of the autoregressive GARCH term, p> 0 and β_j>0, 1≤i≤p, α (L) and β (L) are lag operator polynomials.

3.3.2 Construction of Fluctuation characteristics based on asymmetric GARCH model

In financial markets, the conditional variance of the rate of return on financial assets often shows different responses to positive and negative unexpected returns. For example, negative unexpected gains often cause large conditional variances. This phenomenon is called the asymmetric effect of unknown returns on conditional variance, and the asymmetric GARCH model is required to fit this asymmetric effect. There are mainly TARCH model, ETARCH model and PGARCH model. The difference between these three asymmetric models is mainly reflected on the setting of the variance equation.

(1) TGARCH model.

TGARCH model refers to the use of dummy variables to set a threshold, which is used to distinguish the impact of positive and negative shocks on conditional fluctuations. Taking GARCH (1,1) as an example, to build a TGARCH model with only one threshold, first set up a dummy variable that satisfies the following conditions:

$$\begin{cases} d_{t-1} = 0, \mu_{t-1} \geq 0 \\ d_{t-1} = 1, \mu_{t-1} < 0 \end{cases}$$

Then set up the variance equation of the GARCH model:

$$\sigma_t^2 = \omega + \alpha\mu_{t-1}^2 + \gamma\mu_{t-1}^2 d_{t-1} + \beta\sigma_{t-1}^2$$

As long as γ ≠ 0, there is an asymmetric effect. The term $\mu_{t-1}^2 d_{t-1}$in the conditional variance equation in the above formula is called an asymmetric effect term, or a TARCH term. When good news occurs, $\mu_{t-1} > 0$,there is an impact of α times, at this time $d_{t-1} = 0$.When bad news occurs, $\mu_{t-1} < 0$, there is an (α + γ) impact. If γ> 0, there is a "leverage effect", and the asymmetry will increase the volatility. If γ <0, the asymmetry will reduce the volatility.

(2) EGARCH model.

Through the fitting results of the EGARCH model, we can analyze the leverage effect of the impact of good news and bad news on the price of carbon emissions.

The EGARCH model is the exponential GARCH model. The variance equation analysis is not σ_t^2, but lnσ_t^2, and use the ratio of the disturbance term and the standard deviation of the disturbance term and the ratio of the absolute value of the disturbance term to the standard deviation of the disturbance term are used to capture the impact of positive and negative shocks on the volatility, respectively. The variance equation of the EGARCH (1,1) model can be set as a formula:

$$\ln\sigma_t^2=\alpha_0+\alpha_1\frac{|\mu_{t-1}|}{\sigma_t}+\theta\frac{\mu_{t-1}}{\sigma_t}+\beta_1 ln\sigma_{t-1}$$

When the coefficient estimation value $\beta_1 ln\sigma_{t-1}$in the variance equation of the EGARCH model is positive, it can capture the persistent phenomenon (cluster phenomenon) of volatility often observed in empirical analysis. The asymmetry in the EGARCH model is:

$$\begin{cases}\ln\sigma_t^2=\alpha_0+(\alpha_1+\theta)\dfrac{|\mu_{t-1}|}{\sigma_t}+\beta_1 ln\sigma_{t-1}, \mu_{t-1}>0\\ \ln\sigma_t^2=\alpha_0+(\alpha_1-\theta)\dfrac{|\mu_{t-1}|}{\sigma_t}+\beta_1 ln\sigma_{t-1}, \mu_{t-1}<0\end{cases}$$

If $\theta= 0$, it means that there is no leverage effect in the changes in carbon price fluctuations; if $\theta \neq 0$, it means that there is a leverage effect. When $\theta> 0$, it indicates that the positive news in the carbon market has a greater impact on volatility than the negative news. When $\theta< 0$, then this indicates that the impact of bearish news on volatility is greater than good news.

4. Empirical Analysis

4.1 Descriptive Statistics of Yield Series

4.1.1. Graphic characteristics of the logarithmic rate of return on carbon prices

Graphical characteristics of the logarithmic return on carbon prices. The analysis of the fluctuation characteristics of the logarithmic rate of return of the carbon price of the six carbon pilots shows that there are “fluctuation cluster” effects in the six groups of yield series, and the changes have very obvious characteristics of time-convergence and aggregation: large fluctuations are often followed by large fluctuations, and small fluctuations are often followed by small fluctuations. The fluctuations show irregular changes over time.

4.1.2. Normality test of the logarithmic yield of carbon trading

The statistical characteristics of the quota yields of the various carbon trading pilots are shown in Table 3, all six carbon trading pilots have a skewed yield rate greater than 0, which is a right-skewed distribution. Except for Fujian, the yield of other carbon trading pilot quotas has a kurtosis greater than 3. Combined with its skewness distribution characteristics, it can be seen that the carbon quota trading yield has the "spike and thick tail characteristics" of financial asset returns. 6 carbon quota rate of return J - B statistic at 5% level have passed the test of significance, indicating that the pilot carbon trading with a turnover rate of return declined to normal.

Table.3. Basic statistical characteristics of the logarithmic return series of carbon trading prices

variable	Mean	Std.Dev	Skewness	Kurtosis	Jarque-Bera
RBEA	5.59e-05	0.082649	0.636208	9.579843	952.2991 ***
RSHEA	-0.000701	0.051448	0.236870	4.257274	33.01953 ***
RGDEA	-0.000676	0.053065	0.475239	20.74151	8522.946 ***
RHBEA	-0.0000455	0.038506	0.066054	6.104168	281.1527 ***
RCQEA	-0.001666	0.170792	0.593007	7.245109	277.6525 ***
RFJEA	0.003206	0.066090	0.154708	1.954222	22.69751 ***

Note: *** means passing the significance test at the level of 1% of the variable, ** means passing the significance test at the level of 5% of the variable, and * means passing the significance test at the level of 10% of the variable.

4.2 Unit root inspection

In order to conduct an empirical study on the yield sequences of the 6 carbon trading markets in China, it is necessary to avoid false regressions. This paper chooses the ADF unit root test to verify the existence of false regression. The ADF unit root test results of the 6 carbon emission trading market yield series show that the entire yield series rejects the null hypothesis at the level of 1%, indicating that the 6 carbon emission trading market yield series are all stable series, and ARCH series models can be used for empirical research.

4.3 Residual sequence correlation test

After performing the stationary test on the yield series, the serial correlation needs to be further tested. The order of the mean equation is established according to the correlation lag order.

Table.4. Auto-correlation test of carbon allowance return series

	RBEA	RSHEA	RGDEA	RHBEA	RCQEA	RFJEA
Autocorrelation order	1	5	1	1	3	1

The above results indicate that there are autocorrelations in the carbon price-return residual series of the 6 carbon pilots, and the autoregressive conditional heteroscedasticity model can be used to analyze the data of each carbon emission trading center. Construct a suitable mean equation based on the autocorrelation test results of the carbon allowance returns of each pilot:

$$r_t=\beta_0+\beta_1 r_{t-1}+\cdots+\beta_i r_{t-i}+\varepsilon_t \tag{1}$$

Among them, $\varepsilon_t\left|\left(v_{t,}\ \varepsilon_{t-1,}\ \varepsilon_{t-2,}\ \cdots\right)\sim N(0,\sigma_t^2)\right.$

4.4 Heteroscedasticity test

Take the carbon quota yield sequence of each carbon trading pilot into formula (1) for OLS regression, and perform conditional heteroscedasticity test on formula (1). The test results are shown in Table 5:

Table.5. Conditional heteroscedasticity test

	RBEA	RSHEA	RGDEA	RHBEA	RCQEA	RFJEA
F statistic	2.67 *	8.69 ***	30.53 ***	4.48 **	3.06 **	11.9 ***

It can be seen from Table 5 that the conditional heteroscedasticity test results of the carbon quota returns of each pilot are all less than 10 % , that is, the residual sequence of formula (1) has conditional heteroscedasticity. The existence of heteroscedasticity in the logarithmic return sequence of carbon prices in the pilot regions indicates that the carbon prices in each region have extreme price fluctuations and extreme risks, and that the fluctuations of the carbon price yield sequence in each region are quite different.

4.5 ARCH Effect Test

The ARCH-LM test was used to test the existence of ARCH effect. Firstly, based on the regression results of the mean equation, an autocorrelation plot of the squared sequence of the residuals is made. The partial autocorrelation function plot has several levels of truncation, and the ARCH LM test has several levels of lag.

The F statistic is the statistic of the joint significance test of all the squared lags of the residuals. The P values corresponding to the F statistic are all less than 0.05, which indicates that the logarithmic return series of carbon prices in the pilot area has an ARCH effect. A GARCH model can be established.

4.6 Empirical Analysis of GARCH Model Based on Volatile Long-Term Memory Effect

The GARCH model was used to model the carbon price return series of each pilot and the volatility of the return series was analyzed. Common GARCH models are GARCH (1,1), GARCH (1,2), GARCH (2,1), GARCH (2,2). First of all, it is necessary to use information criteria to judge and select a suitable model for modeling. The model is fitted by Eviews 8.0 software. The results are shown in Table 3, GARCH (1,1) has the best fitting effect, and its parameter estimates are shown in the table 6:

Table.6. Liu Jia carbon emissions trading market return series GARCH (1, 1) model parameters and equations variance estimation results

	project	Beijing	Shanghai	Guangdong	Chongqing	Fujian	Hubei
Mean equation	C	-0.00354 5	-0.001091	-0.001193	0.001728	0.006078	-1.05E-05
	AR (1)	-0.098748	-0.276602	-0.337378	0.255516	0.200719	-0.240121
	AR (2)		-0.208278		0.087565		
	AR (3)		-0.154846		0.050710		
	AR (4)		-0.192598				
	AR (5)		-0.139072				
Variance equation	α_0	0.001975	0.000179	0.000435	0.013400	0.000599	0.000154
	α_1	0.692218	0.284948	0.547285	0.353105	0.293713	0.173854
	β_1	0.146747 (0.0114)	0.665201 (0)	-0.408070 (0)	0.161406 (0.4527)	0.577842 (0.0002)	0.743148 (0)
	α_1+β_1	0.838965	0.950149	0.139215	0.514556	0.871555	0.917002
	AIC	-2.562330	-3.352027	-3.478505	-0.829968	-0.2619485	-3.625878
	SC	-2.512529	-3.261711	-3.428707	-0.751137	-2.569685	-3.576078

Note: The variance equation is $\sigma_t^2=\alpha_0+\alpha_1\mu_{t-1}^2+\beta_1\sigma_{t-1}^2$, the value of α_1 is an ARCH term coefficient, which represents the impact of yield fluctuations on itself. The larger the value of α_1 indicates that the volatility of returns has a long-term impact on itself, that is, it has long-term memory; β_1 is the GARCH term coefficient, which represents the impact of external market factors on the rate of return.

The results show that the GARCH term coefficient of the Hubei carbon price return series is the largest, 0.743148, indicating that the conditional variance of the carbon price is mainly affected by the historical conditional variance; The ARCH term coefficient of Beijing's carbon price yield series is the largest at 0.692218, indicating that carbon price volatility is mainly affected by external shocks. Except for the Chongqing pilot, the GARCH term coefficients of carbon markets in other pilot regions are all significant, indicating that the yield series and its previous historical period Yields are significantly correlated. In addition, in the variance equations of carbon price yields in Beijing, Shanghai, Fujian, and Hubei, the value of α + β satisfies the constraint that the coefficient is less than 1, and the value of α + β in the variance equation of Shanghai carbon price returns is closest to 1, which it shows that the impact of external positive and negative information will have a continuous effect on conditional variance, and this effect will be medium and long-term.

4.7 Construction of Fluctuation characteristics model based on asymmetric GARCH model

4.7.1 TARCH model

Next, use the T-GARCH model to continue to study whether there is asymmetry in the impact of positive or negative news on the yield sequence. The research results are shown in Table 7 below.

Table.7. carbon price logarithmic rate of return TARCH estimation and model TARCH estimated variance equation model results

	project	Beijing	Shanghai	Guangdong	Chongqing	Fujian	Hubei
Mean equation	C_1	-0.006099	-0.001935	- 0.00245 0	- 0.007965	0.004933	0.000866
	AR (1)	-0.109346	-0.248969	- 0. 344 507	0.259572	0.197595	- 0.195111
	AR (2)		-0.175592		0.089782		
	AR (3)		-0.141327		0.044808		
	AR (4)		-0.170611				
	AR (5)		-0.128906				
Variance equation	C_2	0.001494	0.000145	0.000399	0.000399	0.000592	0.000253
	α	0.25 8652	0.105259	0.239884	0.131127	0.250486	0.426226
	β	0.795607 (0.0058)	0.318712 (0.0066)	0.502422 (0.0001)	0.380593 (0.04)	0.089833 (0.6407)	- 0.333815 (0.0222)
	φ	0.290310	0.708384	0.460842	0.169628	0.579162	0.632726

	$\alpha+\varphi$	1.054259	0.423971	0.742306	0.51172	0.340319	0.092411
	AIC	- 2.593152	- 3.370165	- 3.490484	- 0.838092	- 2.616318	- 3.632985
	SC	- 2.569489	- 3.269814	- 3.430724	- 0.748000	- 2.556558	- 3.573225

Note: The C_2 constant term is the ARCH term, the asymmetric term, and the GARCH term.

Based on the TGARCH results, it can be seen that in the T-GARCH models of the yield series of the six carbon trading markets, the leverage factors are not 0. There are asymmetric effects on the yield sequence fluctuations on Beijing, Shanghai, Guangdong, Chongqing, and Hubei carbon prices. Among them, there are a positive leverage effect on the price of carbon emission rights. Good news is more volatile than yield news on the yield sequence Sex has a greater impact. The significance P value of the estimated asymmetry coefficient of the Fujian carbon market is 0.6407, which is not significant at the 10% significance level. Therefore, the T-GARCH model believes that there is no asymmetry effect in the Fujian carbon price return series.

Except for the Beijing carbon market, Shanghai, Guangdong, Chongqing, and Hubei carbon emission rights return sequence fluctuation persistence coefficient $\alpha+\varphi$ satisfies the constraint condition of less than 1 but not close to 1, that is, the impact of the application of external positive and negative information will not produce a return sequence Ongoing effects, external positive or negative news have an impact on the price of carbon emissions in the short term.

If there is good news in the market that is conducive to carbon emissions trading, the impact on carbon emission prices in Beijing, Shanghai, Guangdong, Chongqing, and Hubei at this time is 0.256852 times, 0.105259 times, 0.239884 times, 0.131127 times, and 0.426226 times, respectively. If there is bad news in the market that is not conducive to carbon emissions trading, the impact on carbon emission prices in Beijing, Shanghai, Guangdong, Chongqing, and Hubei at this time will be 1.054259 times, 0.423971 times, 0.742306 times, 0.51172 times, and 0.092411 times.

By comparing these data, we can see that Beijing, Shanghai, Guangdong, and Chongqing carbon emissions trading markets face more bad news than good news. Hubei's carbon emissions trading market is facing more good news than bad news.

4.7.2 EGARCH model

The estimated results of the EGARCH model are shown in Table 8. In the EGARCH fitting results, the coefficient estimates of the asymmetry terms of Beijing, Guangdong, Chongqing, and Fujian are statistically significant, indicating that the overall returns of these four carbon markets are significant. The asymmetric effect, that is, investors' reaction to the good news and the bad news is not consistent. Specifically, when there is good news, fluctuations in the price of carbon emission rights in Beijing, Guangdong, Chongqing, Fujian, and Hubei will be affected by 0.536927, 0.486703, 0.428816, 0.482224, and 0.502641 times respectively; when negative news appears The fluctuations in the price of carbon emissions in Beijing, Guangdong, Chongqing, and Fujian will be affected by 0.913475, 0.917457, 0.708082, 0.575384, and 0.220157 times, respectively. The coefficient of the asymmetric term in Shanghai failed to pass the significance test, indicating that there is no asymmetry in the yield sequence of the Shanghai carbon pilot, but its coefficient is not 0 and greater than 0, which can be considered as a weak leverage effect.

Table.8. E ARCH model estimates of the logarithmic yield of carbon price and the variance results of the EGARCH model

	project	Beijing	Shanghai	Guangdong	Chongqing	Fujian	Hubei
Mean equation	C_1	-0.00 9814	-0.00 0373	- 0.00 1214	- 0.00 4635	0.005400	0.001337
	AR (1)	-0. 032988	0.005000	- 0.3 64364	0.25 9923	0. 213418	- 0.199428
	AR (2)		0.005000		0.0 95508		
	AR (3)		0.005000		0.0 36008		
	AR (4)		0.005000				
	AR (5)		0.005000				
Variance equation	C_3	-2.813067	-5.864164	-2.071138	-2.374423	-1.770296	- 1.092006
	α	0. 725201	0.010000	0.702080	0.568449	0. 528804	0.361399
	β	-0.188274 (0)	0.010000 (0.8951)	-0.215377 (0)	-0.139633 (0)	-0.046580 (0.0048)	0.141242 (0)
	φ	0.559134 (0.0075)	0.010000 (0.8306)	0. 747679 (0.0017)	0. 488346 (0.1310)	0. 760363 (0.6489)	0. 871034 (0.0298)

	AIC	- 2.568553	- 2.972663	- 3.507913	- 0.844092	- 2.618744	- 3.643172
	S C	- 2.508793	- 2.872312	- 3.448153	- 0.754000	- 2.558984	- 3.583412

Note: The C_3 constant term is the ARCH term, the asymmetric term, and the GARCH term.

5. Conclusions and Recommendations

5.1 Conclusion

(1) In the pilot carbon trading market, there are large regional differences in trading activity, trading volume, and prices in various regions. Among them, Hubei's carbon trading is the most active, and its trading volume also ranks first. The average price of Beijing carbon trading is the highest, and the trading price fluctuation is also the largest.

(2) The conditional variance of the Hubei carbon trading price-return sequence is most affected by historical condition variances, while the Beijing carbon trading price-return sequence is mainly affected by external shocks. Beijing, Shanghai, Fujian, and Hubei carbon price yield series have gradually weakened and are weak and efficient markets.

(3) The price of carbon emission rights does not have a long-term continuous response to the positive or negative impact of external information. The impact of good news or negative news on the price of carbon emission rights is short-term.

5.2 Recommendations

(1) Further increase the size of the carbon market and increase the activity of carbon trading

Because Hubei's carbon trading is the most active and the trading volume is also large, local governments can learn from Hubei's carbon trading initial quota release and corporate quota ex post adjustment mechanism to increase the actual carbon emission trading volume and stimulate corporate trading desire. On the one hand, it is necessary to reduce the barriers to entry for enterprises, institutions, and individual investors. The quotas are tightened accordingly, and the market capacity is correspondingly expanded. Market liquidity is further enhanced, and the price discovery function of carbon trading is further enhanced. Enrich and diversify trading varieties to better meet the needs of corporate investment and risk aversion, and increase the activity of the carbon market.

(2) In the construction of a unified national carbon market field process, regulators should the overall height of the carbon market for unified management. This is because different areas of different dependence on carbon exchange policy , influence the type of carbon exchange price factors, the number of different modes of action and the extent of the role , the regional carbon exchange trader information and master the different levels of trading experience , etc. , Leading to the yield curve of the average transaction price of the pilot in each region hasDifferent volatility characteristics , different volatility characteristics hide different levels of risk and different risk structures.

Monitor the price fluctuations of carbon trading in various places to effectively avoid the risks of carbon price fluctuations. Beijing's high carbon trading prices and large fluctuations in yield loss reflect its high cost of carbon emission reduction. Therefore, it is necessary to actively adjust the industrial structure and accelerate the pace of industrial enterprises moving into the deputy capital. The large fluctuations in Shanghai carbon trading prices have increased market trading risks. Therefore, a formal trading platform and a monitoring platform should be established to actively explore ways to increase the participation of trading entities, enhance the transparency of the declaration data of companies included in the emission range, and reduce the risk of market disclosure Misjudgment of trading entities, reducing the impact of external shocks on price returns , and reducing the risk of fluctuations in carbon trading prices.

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