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Empirical Research on the effectiveness of national pilot carbon trading market based on carbon price time series

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Abstract. We will promote the establishment of a unified national carbon market, effectively control and gradually reduce carbon emissions, and contribute to the reduction of carbon emissions, it is of great significance to promote the economic transformation to green and low-carbon. Based on the time series of carbon price, this paper conducts exploratory research on the effectiveness of the carbon trading market in eight pilot regions, uses the fractal market hypothesis, adopts the re-rating difference analysis method, takes the effective carbon price of each pilot every day as the research variable, and empirically analyzes the effectiveness of the pilot carbon market.

1 The introduction

At present, the construction of the national carbon trading market is in a critical period of transition from the pilot area to the national level. The carbon trading market in the pilot area has been operating for several years so far. The study on its operation and market effectiveness will provide important reference value for the construction of a unified carbon market. Based on the theory of fractal market hypothesis, using the method of weighing the poor computing Hurst index (R/S analysis) to analyze the eight pilot migration characteristics of carbon trading market price time series, and then to determine the effectiveness of the market, and based on the empirical results points out current problems in pilot areas of carbon trading market, the unified national carbon trading market put forward policy Suggestions for the construction and improvement ideas.

2 The research reviewed

China's carbon trading market has not been built for a long time, and there are many studies on the effectiveness of China's single carbon trading market. Wang Yanglei et al. (2015) used the fractal market theory to verify whether China's carbon financial trading market has the characteristics of being weak and effective, analyzed the relevant data of Beijing's carbon emission trading market, and concluded that the efficiency of this market has not reached the level of weak and effective. Zhao Lixiang and Tu Lili (2018) took Beijing, Shanghai, Guangdong and Hubei as examples to study the effectiveness of China's carbon trading market, and the results showed that China's secondary carbon trading market is a weak trading market. Among them, Beijing's secondary carbon trading market is a weak type of invalid market; Shanghai and Guangdong are weak invalid markets, but with the increase of carbon holding period, the market efficiency is constantly enhanced. Hubei province has reached the weak effective level. Lu Jingye et al. (2018) conducted GARCH model analysis on the return rate series composed of data of 1123 trading days in the carbon trading market of Hubei Province, and found that the volatility aggregation of the return rate series indicates that the market does not satisfy the premise of weak type market.

3 Empirical analysis on the effectiveness of carbon trading market in pilot areas

Based on the fractal market hypothesis, the basic steps of evaluating market effectiveness by using R/S analysis method to calculate Hurst index are as follows: obtaining the continuous closing price of the market, processing the sequence, obtaining the index equation, and then obtaining the evaluation conclusion through index analysis.

The following takes HuBei carbon trading pilot market as an example to demonstrate the specific calculation principle of Hurst index. All the processes are realized through Python programming.

1.The input data is the closing price sequence of length M (hubei market is 1537). Take the logarithm and make difference to turn it into a logarithmic difference sequence with length N= m-1:

$$N_i = \log_e\left(\frac{M_{i+1}}{M_i}\right), i = 1,2 \dots, M-1 \qquad (1)$$

This converts the input price sequence into a logarithmic return sequence.

2.The logarithmic return rate sequence with length N is equally divided into A subsets, and the length of each subset is N =N/A. Calculate the mean of each subset, denoted as $e_a, a = 1,2 \dots, A$.

3.Within each subset a, count the first k points (k=1,2... N) Cumulative deviation relative to the mean of this subset:

$$X_{k,a} = \sum_{i=1}^{k}(N_{i,a} - e_a), k = 1,2 \dots, n \quad (2)$$

4.Calculate the fluctuation range of logarithmic return rate sequence within each subset a, which is equal to the difference between the maximum and minimum cumulative deviation:

$$R_a = \max(X_{k,a}) - \min(X_{k,a}), 1 \le k \le n \quad (3)$$

5.Within each subset acalculate the standard deviation of the logarithmic return sequence S_a.

6.The fluctuation range of standard deviation is standardized to obtain the heavy scale difference R_a/S_a.Starting from the second step, for the length n selected, we have A subset, so there are A multiple scale range. Their mean is taken as the re-scale range of the original logarithmic price series over a time span of length n, remember to $(\frac{R}{S})_n$.

$$(\frac{R}{S})_n = \frac{1}{A}\sum_{a=1}^{A} R_a/S_a \quad (4)$$

7. By increasing the value of n and repeating the first six steps, the re-scale range of logarithmic price series over time spans of different lengths is obtained.

Table 1 lists the (R/S) calculation results of the logarithmic rate of return series of prices in hubei pilot carbon trading market when n is taken at different values.

Table 1. Hubei carbon trading market severe range

n	$(\frac{R}{S})_n$	n	$(\frac{R}{S})_n$
5	1. 699287	495	25. 60397
15	3. 524801	535	31. 32021
35	5. 769541	625	32. 38910
65	8. 247262	715	35. 51022
105	10. 54191	1015	36. 83001
155	12. 38052	1115	38. 88958
215	16. 03953	1235	48. 06729
285	19. 14806	1275	50. 36905
345	21. 70722	1355	54. 80834

According to the definition of Hurst exponent, it describes the ratio of $(\frac{R}{S})_n$ to n^H. Namely $(\frac{R}{S})_n = C * n^H$. So we performed a logarithmic regression between n and $(\frac{R}{S})_n$ from the previous step to get the regression equation, where the intercept is constant C and the slope is Hurst exponent.

Hurst index equation of Pilot carbon trading market in Hubei province:

$$\log\left[\left(\frac{R}{S}\right)_n\right] = -0.192708 + 0.596473\log(n) \quad (5)$$

Similarly, we can get the other 7 pilot carbon trading market Hurst index equations according to the above steps, and conduct significance test of regression effect on them. The statistical results are shown in the following table:

Table 2. Regression effect test

Pilot areas	Hurst index	T statistic	P statistic
Shenzhen	0. 317557	50. 655	0. 0000
Beijing	0. 348972	78. 349	0. 0000
Shanghai	0. 605039	161. 538	0. 0000
Guangdong	0. 605196	157. 214	0. 0000
Hubei	0. 566473	245. 421	0. 0000
Tianjin	0. 580237	143. 876	0. 0000
Chongqing	0. 601828	204. 568	0. 0000
Fujian	0. 413014	49. 515	0. 0000

As can be seen from the above table, the Hurst index of the carbon trading market in the eight pilot areas all falls between 0 and 1, indicating that there is no large statistical error or code running error in the calculation process. Meanwhile, according to T test results, P values of Hurst index in all pilot areas are significant, indicating a good fitting degree of regression equation.

4 Results

4.1 Empirical Conclusions

1.Effectiveness of the existing state of the pilot carbon trading market. According to the calculation results of Hurst index, all pilot areas do not fall within the range of [0.45,0.55]. Such results indicate that all pilot markets do not walk randomly with market conditions at the current stage and do not reach the weakly effective fractal market.

To be specific, except for Shenzhen, Beijing and Fujian, Hurst index in other regions is all greater than 0.55, which indicates that the carbon trading price in these regions shows obvious persistence and continuity, and the current price trend will affect the future price development to a large extent. As a relatively mature and stable market in China, Hurst index in Shenzhen and Beijing is obviously less than 0.5. In the fractal market theory, it is generally believed that this situation may be caused by price jumps due to policy regulation, and the market regulation role is not obvious.

2.The closing price sequence of the pilot carbon trading market is nonlinear. As Hurst index in all regions is not 0.5, it indicates that the information in the market is transmitted to potential investors in a non-linear way, so investors make judgments. As a result, the closing price sequence also presents a non-linear pattern.

4.2 Cause Analysis

By analyzing the trading situation of each pilot market, we believe that the reasons for the above empirical results are as follows:

1.Carbon price is too low due to oversupply of carbon quota. The reason for the surplus of free quota is mainly due to the macroeconomic situation, the change of industrial structure and energy structure [16]. Whether the government adopts a "top-down" or "bottom-up" approach to set aggregate supply before market operation, it is based on assumptions and forecasts such as economic growth and emission reduction costs. But the actual situation often leads to the carbon emission trajectory deviates from the expectation, resulting in the total set is loose. For example, in the second period of implementation, hubei province underestimated the economic downturn, resulting in the supply of carbon quota far exceeding the demand, thus causing the carbon price to fall sharply. Too low a price also leads to a lack of incentive for enterprises to participate in carbon trading, making the trading system in an insignificant position.

2.The discontinuity of policies affects price expectations. According to the classification market theory, the reason for the jump and even reversal of price changes is likely to come from the policy regulation and interference [17]. Due to the late establishment and insufficient preparation time of China's carbon market, pilot regions often constantly introduce policies to improve the trading framework after the establishment of the market according to their own conditions. Because of their inexperience, these policies tend to have poor continuity and impact on market prices. The Beijing region once introduced a multi-year quota system that resulted in a surplus of quotas and a lack of policies to adjust and remedy the situation in a timely manner, leading to a sharp drop in prices. The phenomenon is also demonstrated by the fact that Hurst index in Beijing is far less than 0.5.

3.Insufficient performance driving force of control and scheduling subjects. From the trading situation of various regions, carbon trading volume and trading volume gradually increase when the performance deadline approaches, while in a large number of trading days that are not near the deadline, the trading volume in many regions is zero. This is because high-emission enterprises, which are the main emission control enterprises in the market, tend to save rather than trade for fear that their quota will not be used in the future. This tendency often leads to insufficient market liquidity in the initial stage of a trading market and then market failure.

4.Single demand side. From the analysis of transaction structure in various regions, the single demand side is a common phenomenon. Although the carbon trading market allows diversified investors to enter, in the initial stage of the market, policies often restrict the access of effective investors to the market. For example, the Regulations of The State Council no. 37 and 38 prohibit continuous trading and centralized trading. The single demand side often leads to the failure to diversify market risks and play the role of market stabilizer.

5 Revelation

The establishment and effective operation of a national unified carbon trading market is of great significance to the transformation of China's economy from extensive growth to intensive growth. At present, there are still many problems in the carbon market in pilot areas of China. Based on the above research in this paper, the following enlightenment can be obtained:

1. The relationship between the government and the market should be handled well, and the role of the market and the government in the construction of the carbon trading market should be given full play. As a market developed by policy, the carbon market should deal with the relationship between the market and the government. The market plays a decisive role, and the government should also play a good role. It is based on the market, but cannot do without government guidance. Therefore, in the subsequent development, the positioning of the two should be clarified. First of all, the government should be a good market designer and supervisor, the most basic rule design is led by the government; The market should lead the transaction behavior, the spontaneous correction of prices, the government to play a supporting role.

2. Scientifically set the total amount of free carbon quota to increase the pressure on emission reduction of emission control enterprises. The amount of the carbon quota determines the scarcity of the quota and directly affects the quota price of the carbon market. Market participants should be aware that only by actively participating in carbon trading can production costs be reduced. The participation of enterprises in carbon trading is not only to fulfill the obligations, but also to give play to its driving force to promote technological innovation and industrial development. In addition, to increase the liquidity of the market, more companies need to be attracted to participate in carbon emission trading. The stability of carbon price mainly depends on the increase of market participants and the frequency of market trading activities. Therefore, more enterprises should be encouraged to participate in carbon emission trading.

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3.Raise emission reduction targets and measures to the legal level as soon as possible, and improve the legal system of carbon trading market. Although the carbon trading market is seen as an effective formula for energy conservation and emission reduction, various policy measures need to complement and synergize with energy policies. For example, carbon trading can be explored to completely replace subsidy policies to solve the problem of multiple subsidies in different regions due to different policies.

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