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Q1 Complexity of carbon market from multi-scale entropy analysis

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HIGHLIGHTS

- EUA carbon future prices are studied with multi-scale entropy analysis.
- Moving average is adopted to calculate the entropy.
- Daily price return follows the mean reversion law in long run.
- Complexity of carbon market corresponds to the extreme socio-political events.

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ABSTRACT

Complexity of carbon market is the consequence of economic dynamics and extreme social political events in global carbon markets. The multi-scale entropy can measure the long-term structures in the daily price return time series. By using multi-scale entropy analysis, we explore the complexity of carbon market and mean reversion trend of daily price return. The logarithmic difference of data Dec16 from August 6, 2010 to May 22, 2015 is selected as the sample. The entropy is higher in small time scale, while lower in large. The dependence of the entropy on the time scale reveals the mean reversion of carbon prices return in the long run. A relatively great fluctuation over some short time period indicates that the complexity of carbon market evolves consistently with economic development track and the events of international climate conferences.

1. Introduction

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The massive emissions of greenhouse gases have seriously affected the global ecological balance and the harmonious between human and nature. The green low-carbon economy with limiting greenhouse gas emissions and mitigating climate change has became global consensus. Based on this background, carbon trading market came into being. The daily price return is a main factor reflecting complexity of carbon market. Currently the European Union emissions trading system is the world's largest carbon trading market, which has been carried to third stage (2013–2020). Among them, the "Union Allowance European" (EUA) trading volume plays an important role in global carbon trading. The EU began carried on the EUA spot trading in 2005. Subsequently they successively implemented the EUA futures, option contracts and other derivative transactions, in which the trading volume of EUA futures is the largest. Its trading price has become an important reference for other carbon emission reduction units. In general, the EUA price fluctuations affects the transactions of the

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global carbon trading market. Discussing the complexity of carbon market and long-term trend of return of carbon prices has great significance.

At present, research about the carbon prices gradually concentrates on the carbon price distribution and behavior and the carbon prices analysis adopting the measurement model. Hintermann [1] researched the relationship between the variation of weather factors and carbon prices, which indicated that the variation of weather factors would effected the fluctuation of carbon prices and there existed nonlinear relationship between the extreme cold weather and carbon prices. Alberola [2] found that carbon prices occurred structural mutation and the policy and system effected the variation of carbon prices from the breakpoint of carbon prices mutations. Convery and Redmond [3] verified the carbon prices of EU's first stage, which showed that the impactor influencing the carbon prices fluctuation is energy prices. Feng et al. [4] identified that the carbon prices was a biased random walk distribution and had some irregular market characteristics by adopting random walk model and R/S analysis. Besides, the influence for carbon's history prices to future development was short. Seifert et al. [5] researched the carbon spot prices for the carbon emissions market of the EU. By establishing the stochastic general equilibrium model to carry out the quantitative analysis, the results showed that the spot price was related to the cost of carbon emissions quota and EU penalty cost. Besides, carbon spot prices have not shown some seasonal characteristics. Chevallier [6] investigated the EU's carbon futures and option price volatility by constructing GARCH model and B–S model, which found that the carbon prices was influenced by economic mechanism, quota and energy price and the unstable environment.

These researches above lay foundation for the carbon prices analysis from macroscopic theory and supposes strong reference for model selecting to measure analysis. As to the authors' limit, there have not been any scholars studied complexity mechanism of carbon prices or explored its intrinsic evolution law by adopting multi-scale entropy from the systematic trend of carbon prices.

Entropy is nonlinear dynamic parameter measuring dynamic system's disorder and uncertainty, which has been applied to many science field. Darbellay and Wuertz [7] analyzed several financial time series and demonstrated the validity of entropy method. Oh et al. [8] verified that the entropy could be used to measure the effectiveness of foreign exchange markets. Martina et al. [9] studied the dynamic characteristic of WTI spot prices by multi-scale entropy, which revealed the relationship between oil market structure and macroeconomic situation and social political extremes. It has been pointed [10] that the entropy analysis performed better than Hurst analysis for small length time series and could detect sharp changes in efficiency without specifying an evolution model.

Recently, the multi-scale entropy has been applied to many science field. The entropy is an index of the quantity of information contained in a time series. High entropy can be related to low predictability of the market dynamics. One of the most generally adopted is the sample entropy (SampEn) [11], which characterizes complexity strictly on a time scale based on the sampling procedure. However, the long-term structures in the time series cannot be captured by SampEn. Hence, Costa [12] proposed the conventional multi-scale entropy (MSE) algorithm, which involves coarse-graining $y_j^\tau = \frac{1}{\tau}\sum_{i=(j-1)\tau+1}^{j\tau} x_i,\ 1 \le j \le \frac{N}{\tau},\ 1 \le k \le \tau$ of the original time series x_t. Wu et al. [13] proposed the composite multiscale entropy (CMSE), which based on the coarse-graining $y_{k,j}^{(\tau)} = \frac{1}{\tau}\sum_{i=(j-1)\tau+k}^{j\tau+k-1},\ 1 \le j \le \frac{N}{\tau},\ 1 \le k \le \tau$. It is shown that for large length of time series, CMSE approximates to MSE quite well. However, as the coarse-graining procedure reduces the length of a time series, the conventional MSE algorithm and CMSE algorithm may lead to an imprecise estimation of entropy when they are applied to a short-term time series. To overcome this obstacle, the coarse-graining procedure was replaced with a moving-average procedure [14] in calculating multi-scale entropy.

This study will adopt multi-scale entropy method to analyze the complexity and intrinsic evolution of carbon market in EU third stage. We want to know if the evolution law of carbon market depend on time scale, if obvious fluctuations in carbon market coincide with the exogenous socio-political events.

The remainder of the paper is structured as follows. Section 2 describes the data source in the paper. Section 3 presents the multi-scale entropy method. Section 4 reports experiment results and discussion. Section 5 provides the overall conclusion.

2. Data description

Carbon futures prices of the EU allowance (EUA) are considered in this paper. Data from the European Climate Exchange (ECX). Locating in London, the ECX is the largest carbon market under the EU ETS, in which there are spot, futures, options of the EU allowance (EUA) and Certified Emission Reduction(CER) and the trading volume of EUA is the largest. The carbon futures prices Dec16 are selected as the experimental data, which coming from the EUA. For Dec16, limited to the website permission, the daily trading data from August 6, 2010 to May 22, 2015 are chosen, exclusive of public holidays, with a total of 1219 observations. Fig. 1 represents the trend of original data Dec16 from August 6, 2010 to May 22, 2015. Let P_t denote the carbon prices Dec16 on day t. The daily price return $x_t = \log(P_t) - \log(P_{t-1})$ is adopted as the experiment data, which is exhibited in Fig. 2, showing complex behavior with random components.

3. Methodology

Entropy is usually adopted to quantify disorder and uncertainty of dynamic systems and further judge the diversity of the system. In this section, we will introduce the basic concepts and computation algorithm of sample entropy and multi-scale entropy.

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