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Statistical regularities of Carbon emission trading market: Evidence from European Union allowances

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HIGHLIGHTS

- The PDF of daily return shows higher peak and fatter tail than normal distribution.
- We find significant relationship exists between EUA and almost all financial assets.
- The EUA shows different correlation behavior from any other currency futures.
- The EUA shows much higher correlations with several relevant commodities than other commodities.

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ABSTRACT

As an emerging financial market, the trading value of carbon emission trading market has definitely increased. In recent years, the carbon emission allowances have already become a way of investment. They are bought and sold not only by carbon emitters but also by investors. In this paper, we analyzed the price fluctuations of the European Union allowances (EUA) futures in European Climate Exchange (ECX) market from 2007 to 2011. The symmetric and power-law probability density function of return time series was displayed. We found that there are only short-range correlations in price changes (return), while long-range correlations in the absolute of price changes (volatility). Further, detrended fluctuation analysis (DFA) approach was applied with focus on long-range autocorrelations and Hurst exponent. We observed long-range power-law autocorrelations in the volatility that quantify risk, and found that they decay much more slowly than the autocorrelation of return time series. Our analysis also showed that the significant cross correlations exist between return time series of EUA and many other returns. These cross correlations exist in a wide range of fields, including stock markets, energy concerned commodities futures, and financial futures. The significant cross-correlations between energy concerned futures and EUA indicate the physical relationship between carbon emission and energy production process. Additionally, the cross-correlations between financial futures and EUA indicate that the speculation behavior may become an important factor that can affect the price of EUA. Finally we modeled the long-range volatility time series of EUA with a particular version of the GARCH process, and the result also suggests long-range volatility autocorrelations.

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1. Introduction

Since the early 20th century, the earths average surface temperature has increased by approximately 0.8 C, with about two thirds of the increase occurring after 1980. Most climate scientists agree that the global warming over the past century is mainly caused by increasing concentrations of greenhouse gases (GHG) associated with human activities [1]. The increase in global temperature will cause rises of sea levels and changes in the amount and pattern of precipitation, as well as probable expansions of subtropical deserts [2].

To cooperatively prevent dangerous anthropogenic climate change, most countries are now parties to the United Nations Framework Convention on Climate Change (UNFCCC) initiated in 1992 which is known today as the Kyoto protocol. One of the main mechanisms of GHG reduction dictated by the protocol is the trading of human-related emission allowances, primarily the carbon dioxide (CO_2) in organized and competitive markets [3]. Today, several national and regional emission markets have been established in which a variety of specialized financial instruments are traded [4]. Financial markets are of great importance for economics and econophysics research. A key topic of the market studies is the statistical regularities of price dynamics, which could be measured by the price change (return) and its magnitude (volatility) [5]. For example, the long-range autocorrelation of volatility, short-range autocorrelation of return, time-dependent stochastic process, leptokurtic and power-law tail distributions, many stylized facts have been found in temporal field of price time series.

However, the literature is rather sparse about examining the CO_2 allowance prices from the price dynamics angle. Seifert et al. developed a stochastic equilibrium model reflecting the most important features and analyzed the resulting CO_2 spot price dynamics [6]. Pallella and Taschini provided an econometric analysis addressing the unconditional tail behavior and the heteroskedastic dynamics in the returns [7]. Benz and Truck analyzed the short-term spot price behavior and model the returns of CO_2 emission allowances by Markov switching and AR-GARCH models [8]. Feng and Zou investigated the fluctuation of volatility by using random walk model, rescaled range analysis, and ARFIMA model [9].

Europe has emerged as the leader in the emissions trading industry with the European Union Emissions Trading System (EU ETS) being the worlds largest single market for CO_2 emission allowances, accounting for approximately 98% of the global transactions for 2007. The two major instruments traded in the EU ETS are the European Union Allowances (EUA) since 2005 and the Certified Emission Reduction (CER) credits since 2007, with the EUA processing approximately 90% of the screen based trading volume in EU ETS. In this paper we focus on the EUA market, and examine the stylized facts of the price dynamics of EUA trading in the European Climate Exchange (ECX), which is the biggest and leading venue in Europe.

The paper is organized as follows. In Section 2, we introduce the data being analyzed and the definition of return and volatility time series as well as cross-correlation coefficient. In Sections 3 and 4, we show the empirical results of autocorrelation and cross-correlation analyses of return and volatility of EUA prices respectively. In Section 5, we model the volatility of EUA prices by using GARCH model. In Section 6, we summarize our work.

2. Data analyzed

The largest market for carbon trading is the European Union Emissions Trading System (EU ETS). The two major instruments traded in the EU ETS are European Union Allowances (EUA) and Certified Emission Reduction (CER) credits. Each security offsets one metric tonne of CO_2 equivalent. The market size of EUA is much bigger than CER, with the trading volume of EUA being about 10 times of CER (see Ref. [10]). Therefore, in this paper we analyze the daily records (the most actively traded contract) of the EUA database from the European Climate Exchange (ECX), which is the leading venue market relevant. For example, in 2009, the ECX processed 65.6% of the screen based trading volume in EUA. The data cover the period of January 2007 through December 2011.

The total volume of EUA futures trading increased significantly during Phase I (lasted from 2005 to 2007), especially before 2007. Such high-level non-stationarity time series are not suitable for long-memory analysis, which makes the EUA price time series difficult to determine the self-affinity using statistical methods. For this reason, we focused on the period of 2007–2011, during which the EUA prices and total volume roughly keep stability. Therefore we can assume that the data in this period is at least asymptotic stationarity and then be able to check the cross-correlation of EUA and other asset. We also take other 68 daily financial time records during January 2007–December 2011. The data set includes 21 currency futures price time series, 19 commodity futures price time series obtained from http://data.theice.com/ViewData/Default.aspx, and 29 stock market indicator time series obtained from http://finance.yahoo.com.

We first calculate the price change (return) a given financial asset i (such as EUA) as,

$$R_i(t) = \ln P_i(t) - \ln P_i(t-1) \quad (1)$$

where the $P(t)$ denotes the price of a given financial asset i in day t. Since different finance time series have varying levels of standard deviation. Next we normalize the return time series as:

$$g_i(t) = \frac{R_i(t) - \langle R_i(t) \rangle}{\sigma} \quad (2)$$

where $\sigma = \sqrt{\langle R^2 \rangle - \langle R \rangle^2}$ is the standard deviation of $R(t)$ and $\langle \cdots \rangle$ denotes a time average over the period studied. We then compute the cross-correlation between asset i and j as:

$$\rho_{ij} \equiv \langle g_i(t) g_j(t) \rangle. \quad (3)$$