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The efficiency analysis of the European CO_2 futures market

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HIGHLIGHTS

- The study proposes the cointegration test for the market efficiency analysis.
- Vector error correction model (VECM) is used for the price forecast.
- The EU ETS carbon futures market is efficient in one month.
- In the efficient range, the effect of EU ETS market will last 3 months.

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ABSTRACT

The European Union Emissions Trading System (EU ETS) is the main international carbon trading market, in which European Union CO_2 allowances (EUAs) are traded with increasing intensity. In order to help the market participants mitigate the market price risk, one possible way is to analyze the time range of market efficiency and the price discovery mechanism of EUA futures market and spot market. For this purpose, the paper provides the unit root test and the cointegration test for the EUA futures market during 2009–2011. Our result shows that the EUA futures market is efficient within 1 month. Furthermore, it illustrates that the impact of the price will continue for 3 months, examined by a vector error correction model (VECM).

1. Introduction

After the commencement of the Kyoto Protocol in 2005, there has been an explosive growth in the global carbon trading market. The value of the global carbon trading market reached 40 billion euros in 2007, increased by 81.8% of the value in 2006, which was 22 billion euros. The market value for the first half of 2008 even reached the level for the whole year of 2007. The United Nations and the World Bank predict that the annual size of this market would be up to $ 60 billion in the period of 2008–2012, and the market capacity would be $ 150 billion, expecting to replace the oil market as the world's largest market. The EU emissions trading system (EU ETS) is the major international carbon trading market, accounting for the 85.93% and 96.46% of the trading volume and turnover in the international carbon market.

Unlike other markets, emerging carbon market faces greater market price risk in parallel of its rapid development, since it was not only effected by the market mechanism, but also under the impact of the instable exogenous environment, such as national politics (the climate negotiations), the temperature, the financial crisis and other special events.

This paper outlines the time range of the EU ETS market efficiency by unit root test and cointegration test and then make forecast of the futures and spot prices by vector error correction model to help market participants mitigate the market price risk.

2. Literature review

With the rapid development and special mechanism of EU ETS impacts, great attention is being paid to carbon market risk. As previously mentioned, besides the market mechanism, the carbon market is also affected by the national politics (the climate negotiations), the temperature, the financial crisis and other special events. Springer [1] defined the factors that affect the price of carbon emission as national policy, energy prices, and temperature conditions, as well as the economic activities by the theoretical model. Buchner et al. [2] discussed the lessons and general principles of the allocation of allowances in the EU ETS,and analyzed the global implications of the EU ETS. Haar and Haar [3] summarized the uncertainties of the EU ETS policy-making from a qualitative

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view, including the potential impact on economic development, the role of reductions in greenhouse gas emissions, and the benefits and reduction costs. Weather conditions (temperature, rainfall, wind speed) can affect the carbon market by affecting power generating capacity and the demand for emissions allowances. Seifert et al. [4] analyzed the CO_2 spot prices by the random equilibrium model, and he found the trend of the CO_2 spot price did not show seasonal characteristics.

To avoid the carbon market price risk, derivatives trading, such as carbon futures and carbon options is one of the most effective market-oriented measures. Under these circumstances, the research on the efficiency and price discovery of the European carbon futures market is crucial. Current research mainly focused on demonstrating the existence of the equilibrium relationship between the future and spot market in different approaches.

Milunovich [5] analyzed the relationship between futures and spot price of the EU carbon market by the Granger causality test and cointegration test. His result showed that carbon futures was not priced by the cost-of-carry model, but rather depended on the dynamic interaction between some futures prices and spot prices. Both prices change simultaneously and rapidly due to the information shared by the two markets. Eva Benz, Jordis Hengelbrock (2008) analyzed liquidity of the EUA futures market by studying traded bid-ask spreads following the approach of Madhavan et al. (1997) and price discovery by using the VECM framework of [6]. The results indicated that, from 2005 to 2007, liquidity in the European CO_2 futures market has remarkably increased and organized trading has rapidly expanded. Qi and Lu [7] analyzed the price discovery mechanism of Certified Emission Reductions (CERs)futures market and spot market by applying the common factor model, and the similar findings were shown empirically by impulse response functions and variance decomposition. These results indicated that there was a long-run cointegration between CERs futures price and spot price; CERs futures price was Granger cause of spot price in the short-run. Huang et al. [8] made the theoretical and empirical analysis on the price discovery and hedging functions of CER futures market to determine the efficiency of the international carbon market. By Granger test, they found that CER futures market had a good short-term price discovery function, but it was not significant in the long-term. SVAR model further confirmed the connection between spot and futures prices in a short term, but CER and EUA market would reach to a dynamic stability in the long run. Uhrig-Homburg and Wagner (2009) analyzed the spot and futures markets of EU ETS by empirical test and found out price discovery function between them. Rotfu [9] found that the carbon price of spot market (Bluenext) was strongly influenced by carbon futures market, as the strong correlation between them. Milunovich and Joyeux [5] found out the stable long-term relationship between a couple of futures contracts and spot contracts they studied. The bi-directional volatility transfer between them is helpful to the price discovery of carbon futures market. Xu [10] studied carbon emissions characteristics and introduced the futures pricing model based on term structure theory. The carbon emissions pricing issues was solved by the use of price discovery function of carbon futures. The empirical results showed the accuracy of this pricing model.

In summary, all literatures above demonstrated the efficiency of the carbon futures market by various methods, such as cointegration, vector error correction model, the corresponding pulse, and the variance decomposition method. However, none of those methods estimated the time range of the persistence of such efficiency, which would be of little help for other purposes such as prediction on spot price. Also, most of the literatures drew a conclusion just analyzing on only 3–4 kinds of long-term futures contracts, which was not sufficient to reflect the whole futures market.

On the basis of these studies, this paper outlined the time range of the market efficiency by studying all the futures contracts in the European Climate Exchange (ECX), including short and long term contracts. Next, it revealed the cointegration relationship between the spot prices and futures prices by the vector error correction model in this time range, which would serve the further purpose of prediction on the spot price in carbon market.

3. Methodology

3.1. Market efficiency

According to the concept of the market efficiency proposed by the Fama (1970), if the carbon futures market is efficient, it should be a market with price discovery function, reflecting all the available information. In other words, the carbon futures price should be an unbiased estimate of the spot price at the maturity date. That is,

$$E(sp_t - fp_{t-k}|\Phi_{t-k}) = 0 \tag{1}$$

assuming sp_t is the spot price at the maturity date t of the carbon futures, fp_{t-k} is the price of the futures contract at time k before the maturity date. Φ_{t-k} represents all the information you can get at the moment $t-k$.

After explaining the existence of the efficiency of the carbon futures market the next step is to find out the cointegration relationship between the spot prices and futures prices.

3.2. The cointegration test

The cointegration relationship would be tested by the following model:

$$sp_t = \alpha + \beta fp_t + \varepsilon_t \tag{2}$$

The stationarity of the different series of carbon futures prices (fp_t) and the series of the maturity date spot prices (sp_t) is tested by using the unit root test. If a time series become stationary process only after d times difference, then it can be named as $I(d)$. If both series sp_t and fp_t are $I(d)$ and their some kind of linear combination is stationary, the cointegration relationship is existed between them. Only when the cointegration relation is existed, the regression model of carbon futures prices and spot prices can be established.

After the determination of existence of the cointegration relation, the next step is to affirm the form.

3.3. Vector error correction model

Vector error correction model (VECM) is the vector autoregressive (VAR) model with all variable imposed cointegration constraints. And VECM is just suitable for series with cointegration relation.

The model of VAR (P):

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + Bx_t + \varepsilon_t \tag{3}$$

where y_t is m-dimensional non-stationary series, x_t is d-dimensional deterministic variable, ε_t is innovation vector can be deformed as

$$\Delta y_t = \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \Pi y_{t-1} + Bx_t + \varepsilon_t \tag{4}$$

where $\Pi = \sum_{i=1}^{p} A_i - \mathrm{Im}; \Gamma_i = -\sum_{j=i+1}^{p} A_j$

As all the series in the vector of endogenous variables after the first-order differential are stationary, only if all the variable in the