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Testing the martingale difference hypothesis in CO_2 emission allowances[☆]

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ABSTRACT

This study examines the martingale difference hypothesis (MDH) for the carbon emission allowance market within the European Union Emission Trading Scheme (EU ETS) during the Phase I and the Phase II, using both daily and weekly data over the 2005–2009 period. We analyze the MDH for spot prices negotiated on BlueNext, European Energy Exchange and Nord Pool along with futures prices negotiated on BlueNext and European Climate Exchange, using the new variance ratio tests developed by Kim (2009) and the generalized spectral test proposed by Escanciano and Velasco (2006). For the Phase I, the results show that the spot price changes of these three markets are predictable, suggesting the possibility of abnormal returns through speculation, except during the period April 2006 to October 2006, namely after the compliance break and before the ECs of stricter NAP II. Finally, we find that the CO_2 spot and futures price changes are unpredictable during the Phase II because we failed to reject the MDH based on both daily and weekly data. Thus, these markets are found to be weak-form efficient.

1. Introduction

The European Union Emission Trading Scheme (EU ETS) was introduced in January 2005 as the central framework that EU member states should employ to fulfill their obligations under the Kyoto protocol, i.e., to reduce the anthropogenic contribution of greenhouse gas (GHG) emissions (primarily CO_2) in the atmosphere.[1] The EU markets are the largest, most liquid and most developed, covering up to 40% of European CO_2 emissions. The EU ETS has been designed to operate in two initial phases. The first phase (2005–2007, Phase I) is a pilot phase during which the trading volume increased from 262 million metric tons in 2005 to 818 million metric tons in 2006 and to 1.4 billion in 2007. The value of trades reached 30 billion euros in 2007. Phase I established a strong carbon market and provided new business development opportunities for risk management and market operators. The second phase (2008–2012, Phase II) coincides with the period when the EU must meet the 8% decrease from 1990 levels under the Kyoto Protocol. For the post-2012 period, the European Commission (EC, hereafter) has decided to continue the operation of the market. The EU member states have agreed to reduce their GHG emissions by an overall 20% by the 1990 levels under the Kyoto protocol by 2020.[2] To improve the fluidity of the EU ETS, organized allowance trading has been segmented across trading platforms: Nordic Power Exchange (Nord Pool) in Norway arose in February 2005, European Energy Exchange (EEX) emerged in Germany in March 2005, European Climate Exchange (ECX) based in London and Amsterdam started in April 2005, BlueNext launched in France in June 2005,[3] Energy Exchange Austria (EEA) in Austria began in June 2005, and SendeCO2 in Spain started at the end of 2005.

Several relevant research papers have been published in the economics literature on the emission allowance market mechanisms and, policies and their implications.[4] Recently, a growing body of empirical research has been undertaken in a financial market framework, especially on the behavior of emission allowance spot and futures prices, e.g., Alberola et al. (2008), Daskalakis and Markellos (2008), Paolella and

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[1] The protocol is based on a “cap and trade” system. Each country agrees to reduce its overall emissions by 8% of their 1990 levels by the end of 2012. For the 5-year compliance period from 2008 to 2012, entities (nations or companies) that emit less than their quota may sell emission credits to entities that exceed their quota. To help countries achieve their reduction objectives, the Protocol includes three flexibility mechanisms: the creation of an international carbon market, Joint Implementation and the Clean Development Mechanism. Joint Implementation (JI) projects do not create credits, but rather transfer reduction units from one country to another. The aim of Clean Development Mechanism (CDM) projects is to promote investments in developing countries by industrialized nations and to encourage the transfer of low-emission technologies.

[2] See Daskalakis and Markellos (2008) for a discussion of the EU ETS.

[3] Powernext Carbon became BlueNext in January 2008.

[4] See, for example, Rubin (1996), Kling and Rubin (1997), Boemare and Quirion (2002), Kosobud et al. (2002), Svendsen and Vesterdal (2003), Vesterdal and Svendsen (2004), Böhringer and Lange (2005), Ellerman (2005) and Ellerman et al. (2007), Stern (2007), and the Special issue in *Oxford Review of Economic Policy*, (2008, Volume 24, Number 2), among others.

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Taschini (2008), Seifert et al. (2008), Benz and Trück (2009), and Boutaba (2009).[5]

An important question is whether the chosen mechanics of the EU ETS have allowed the market to operate efficiently during the Phase I (2005–2007) and since implementing the Phase II (2008–2012). In other words, do emission allowance prices reflect all available information to the extent that no investor can systematically gain excess returns (Jensen, 1978)? Investigating this issue is crucial, because the prime aim of the EU ETS is to allow the participating countries to achieve environmental compliance in a cost-effective and economically optimal manner, both of which implicitly require that the market itself be efficient. The efficiency of the CO_2 market is particularly important for emission intensive firms, policy makers, risk managers and investors in the emerging class of energy and carbon hedge funds. Carbon market efficiency is intended to enable firms to achieve their emission reductions at minimum cost. One policy implication of inefficient markets is a greater need for regulation to improve information flows and reduce market manipulation.

Since the seminal papers of Samuelson (1965) and Fama (1965), the efficient market hypothesis (EMH thereafter), and more precisely the weak-form informational market hypothesis, states that the information contained in past prices is instantly, fully and perpetually reflected in the asset's current price. This implies that the prices follow a random walk or a martingale.[6] As a result, future price changes are purely unpredictable based on past price information and fluctuate only in response to the random flow of news (see, Fama, 1970, 1991, 1998; Fama and French, 1988; Lo and MacKinlay, 1988; among others). Moreover, given that price adjustment to a new piece of information is instantaneous and accurate, returns cannot be predicted. This means that historical price changes cannot be used to form superior forecasts or to earn trading profits above the level justified by the risk assumed. Most of the EMH studies on financial markets test for weak-form efficiency through the martingale difference hypothesis (MDH thereafter) where the current price is the best predictor of the future price and the returns are independent from (or uncorrelated with) the past values. If the CO_2 emission market is weak-form efficient, then the change in the CO_2 spot price follows a martingale difference sequence (MDS thereafter), and the price changes are unpredictable. This means that it is impossible for a trader to gain excess returns over time through speculation. If the market is not weak-form efficient, then the price changes are predictable. Thus, traders can generate abnormal returns through speculation. For these reasons, the predictability of returns is an important issue in carbon market efficiency. Nevertheless, little attention has been devoted to weak-form efficiency in CO_2 markets. Seifert et al. (2008) show that BlueNext market is efficient, using autocorrelation tests and daily CO_2 spot data from June 24, 2005 to December 15, 2006. Daskalakis and Markellos (2008) assess weak-form efficiency by analyzing spot and futures market data from BlueNext, Nord Pool and ECX, using daily prices covering the period from the first available quote until December 12, 2006. They find that BlueNext and Nord Pool markets are not consistent with weak-form efficiency from variance ratio tests and technical analysis trading rules.

In this paper we extend the examination of the weak-form EMH in the EU ETS markets for CO_2 emission allowances in two ways. First, this study is based on a more extensive sample. We analyze daily data for three spot markets, BlueNext, EEX and Nord Pool, during the Phase I (2005–2008) and the Phase II (2008–2009) to compare the evolution between the two initial phases and these markets. We investigate the EMH over various sub-periods to analyze the effects of the important structural change due to the first disclosure of 2005 verified emissions in April 2006 revealing the long position of each plant, which was accompanied by a sudden allowance price collapse, as well as the EC's announcements of stricter National Allocation Plan (NAP, hereafter) II validation in October 2006, which reinforced the depressive effect on prices. We also consider the daily data for two futures markets, BlueNext and ECX, during the Phase II. Furthermore, we analyze the weekly data for the three spot and the two futures markets to see if the results are robust to different degrees of data aggregation and time horizons. The weekly data can overcome potential problems present in the daily data, which are caused by thin trading, bid–ask spread, and nonsynchronous trading. Second, the unpredictability of the CO_2 spot and futures price changes, which is an implication of weak-form market efficiency, is evaluated using a powerful method: the variance ratio (VR) test.[7] More precisely, we apply the bootstrapped automatic VR test proposed by Kim (2009). This VR test is robust to heteroscedasticity and non-normality which are present in CO_2 emission allowance prices (e.g., Daskalakis and Markellos, 2008; Benz and Trück, 2009; Joyeux and Milunovich, 2010) and possess desirable small sample properties such as high power. We also apply the generalized spectral test developed by Escanciano and Velasco (2006) which can capture possible non-linear dependence (see Escanciano and Lobato, 2009; Charles et al., forthcoming).

The remainder of this paper is organized as follows. Section 2 presents the bootstrapped automatic VR test and the generalized spectral test. Section 3 summarizes the characteristics of the data. The empirical results on the MDH are given in Section 4. The conclusion is drawn in Section 5.

2. Tests for martingale difference hypothesis

2.1. Variance ratio tests

Since the seminal work of Lo and MacKinlay (1988, 1989) and Poterba and Summers (1988), the standard variance ratio test or its improved modifications have been widely used to test for the unpredictability of price changes, including the multiple variance ratio test of Chow and Denning (1993), sign and rank tests of Wright (2000), wild bootstrap test of Kim (2006), and power-transformed test of Chen and Deo (2006).[8]

The VR test is based on the property that, if return is purely random, the variance of k-period return (or k-period differences), $y_t - y_{t-k}$, of the time series y_t, is k times the variance of the one-period return (or the first difference), $y_t - y_{t-1}$. Hence, the VR at lag k, $VR(k)$, defined as the ratio of $1/k$ times the variance of k-period return to that of one-period return, should be equal to one for all values of k.

The VR test evaluates the hypothesis that a given time series or its first difference (or return), $x_t = y_t - y_{t-1}$, is a collection of independent

[5] Papers that have focused on the relationship between spot and futures markets for European Union Allowances (EUAs) include Joyeux and Milunovich (2010), Trück et al. (2007), Alberola and Chevallier (2009), Uhrig-Homburg and Wagner (2009) and Daskalakis et al. (2009).

[6] The terms "random walk" and "martingale" have been interchangeably used in the literature. However, the martingale is less restrictive than the random walk. The martingale difference requires only independence of the conditional expectation of price changes from the available information, as risk neutrality implies, whereas the random walk model requires this and also independence involving the higher conditional moments of the probability distribution of price changes. It is also important to note that there is no equivalence between the two notions (efficiency and random walk): random walk implies the efficiency property, but the non validation of the random walk does not imply that the market is inefficient. See Lo and MacKinlay (2001) for a discussion on MDH and EMH.

[7] Lo and MacKinlay (1989) examined the VR, Dickey–Fuller unit root and Box–Pierce serial correlation tests and found that VR test is more powerful than the others under the heteroscedastic random walk.

[8] See Hoque et al. (2007) and Charles and Darné (2009) for a review.