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Article

Mean reversion of stochastic convenience yields for CO_2 emissions allowances: Empirical evidence from the EU ETS

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ABSTRACT

This paper examines the mean-reversion property and volatility features of stochastic convenience yields for CO_2 emissions allowances by using ADF, ECM-GARCH and ECM-TGARCH models. Empirical results show that the convenience yields for CO_2 emissions allowances exhibit time-varying trends when different maturities are considered, and that convenience yields exhibit a linear mean-reverting process. We also find that the volatility of convenience yields exhibits a mean-reversion process and asymmetric leverage effect using ECM-GARCH (1,1) and ECM-TARCH (1,1) models. Unfavorable market information has a higher impact on this volatility than favorable market information, and unfavorable market information has a lower effect on the long-term volatility of convenience yields.

1. Introduction

In recent years, CO_2 gas emissions have attracted increasing public attention. CO_2 gas emissions control and environmental protection have become hot political and academic topics. Since the launch of the European Union emissions trading scheme (EU ETS) in 2005, CO_2 emissions allowances have become valuable commodities which can be traded in the CO_2 emissions allowances markets. Based on the research report on the state and trend of the carbon market in 2011 by the World Bank, the total value of the global carbon markets had grown 6% to US $144 billion, and the trading volumes had reached 8.7 billion tons. CO_2 emission allowances markets have become significantly promising and liquid commodities markets, and have the potential to grow into the largest commodities markets in the future.

Early empirical results show that spot and futures prices for CO_2 emissions allowances exhibit strong stochastic behavior. Benz and Truck (2006) propose that emissions allowances prices are directly determined by the expected market scarcity in the CO_2 emissions allowances markets. Seifert et al. (2008) and Benz and Trück (2009) find that spot prices exhibit a time-varying volatility structure in the pilot phase. Daskalakis et al. (2009) show that the prohibition of banking and borrowing for emissions allowances between distinct phases in the EU ETS has significant implications in terms of futures and options pricing. Montagnoli and Vries (2010) show, by using variance ratio tests, that Phase I was inefficient, while Phase II shows signs of restoring market efficiency. Milunovich and Joyenx (2010) examine market efficiency and price discovery in CO_2 emissions allowances futures markets in the European Union. Their findings indicate that spot and futures markets can share information efficiently and futures markets contribute to price discovery. Chevallier (2010) proposes a time-varying risk premium between CO_2 spot and futures prices, and that a positive relationship exists between risk premium and time-to-maturity of futures contracts.

Emissions allowances markets are emerging financial markets. Many studies have shown that financial products and commodities price series follow a mean-reverting process which indicates the internal balance mechanism in the price series. Gibson and Schwartz (1990) develop a two-factor model for commodity pricing, where spot price follows a geometric Brownian motion and the convenience yield follows a mean-reverting process. Schwartz (1997) and Miltersen and Schwartz (1998) propose a three-factor model for commodity futures pricing where the commodity spot price, the instantaneous convenience yields, and the instantaneous

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interest rates are important variables. Liu and Tang (2011) show that the volatility of convenience yields is heteroskedastic for industrial commodities, and propose that the heteroskedasticity of the convenience yields predicts an upward sloping implied volatility smile. These signs are of central importance to commodities pricing and commodities options value. The stochastic convenience yield is a significant variable for commodity pricing, and mean-reversion convenience yields are central for forecasting commodity price and estimating hedging returns. Accordingly, in this paper we examine the mean-reverting properties and the volatility features of stochastic convenience yields for CO_2 emissions allowances.

Mean reversion is a tendency toward return to long-run average value over time. Previous studies find that convenience yields show a mean-reverting process in the two-factor and three-factor commodity futures pricing models. Generally speaking, mean-reversion behavior in convenience yields is expected because of the strong tendency, and short-term random convenience yields converge to their mean values in the long run. After temporarily deviating from their equilibrium value, convenience yields always revert toward their equilibrium value, hence the process is mean-reverting. This property of convenience yields is an important hedge and risk management factor for commodity producers, hedgers, financial intermediaries and other market participants.

Immature emissions allowances markets bring about the overreaction in spot and futures prices (see Montagnoli and Vries, 2010; Zhang and Wei, 2011). In the weak-effective emissions allowances markets, spot and futures prices have greater upward risk and downward risk trends, the obvious market risk changes bring market participants about tremendous uncertainty in assets portfolio between spot and futures for emissions allowances. The convenience yields are potential benefits implied from emissions allowances markets and the above early literatures on emissions allowances do not propose empirical results in mean reversion property and volatility features of convenience yields. Mean reversion property and volatility features of convenience yields are central to accurately predicting futures options pricing and making correct assets portfolio hedging policies.

The main innovations of this paper are that we capture mean-reversion property and asymmetric leverage effects in convenience yields for emissions allowances by using the ECM-GARCH and ECM-TARCH models. These empirical results are helpful for capturing market price behavior and explaining the spread between spot and futures prices. They are also helpful for accurately adjusting assets portfolio sizes between spot and futures and achieving the greater assets portfolio revenues.

The remainder of our paper is organized as follows. Section 2 describes the sourcing of data samples. Section 3 analyzes the statistical analysis results in convenience yields for CO_2 emissions allowances. Section 4 proposes mean-reversion empirical methodology. Section 5 estimates and discusses the empirical results. Section 6 provides a brief conclusion.

2. Data description

The EU ETS is the largest greenhouse gas (GHG) emissions trading system in the world. It has experienced two phrases: the Pilot phase (2005–2007) and the Kyoto phase (2008–2012). The CO_2 emission rights, called EU allowances (EUA), allow for the right to emit one ton of CO_2 into the atmosphere under the European Union emissions trading scheme (EU ETS). The minimum trading volume for each standard futures contract is 1000 tons of CO_2 equivalents. In this paper, we select data samples from the settlement spot and futures prices in the BlueNext and ICE exchange platform. Spot trading in the BlueNext exchange was introduced on June 24, 2005, and now BlueNext has become the most liquid platform for CO_2 spot trading. ICE has become the most liquid platform for CO_2 futures trading since its introduction on April 22, 2005.

After the European Union banned out-of-phase banking and borrowing, the spot price for CO_2 emissions allowances fell down to zero from October 2006 to December 2007 (see Chevallier, 2010). The trading of futures contracts with vintages December 2013 and 2014 was introduced on April 8, 2008. We select data samples from time-varying settlement prices on EUA futures contracts with different maturities from December 2010 to December 2014. Considering the availability and continuity of EUA futures prices, we choose these data samples to cover the period from April 8, 2008 to December 20, 2010 in the Kyoto phase. Here we choose as the constant free-risk rate, the average coupon rate of 3.06% which was the rate for three-year government bonds issued in 2010 in the European Union.

In Fig. 1, S denotes spot price for CO_2 emissions allowances, F_1 denotes the EUA futures contracts that are closest to maturity, F_2 denotes the second closest to maturity, and F_3, F_4, F_5 are defined similarly. From Fig. 1, we obviously observe that CO_2 price series for both spot and futures contracts with different maturities exhibit strongly time-varying trends throughout the sample period.

3. Convenience yields for CO_2 emissions allowances

Convenience yields are defined as the immediate benefit or risk premium associated with holding underlying products or physical commodities at hand. Spot holders can achieve potential benefits due to price volatility, but the holders of futures contracts cannot attain such benefits (see Working, 1949; Brennan, 1958). The prices of CO_2 emissions allowances exhibit random trends,

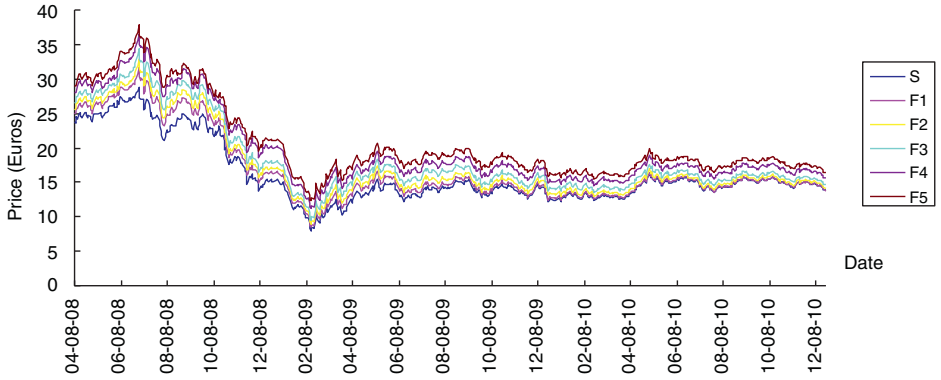

Fig. 1. Time series in spot and futures prices for EUA emissions allowances.