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Stochastic volatility of the futures prices of emission allowances: Bayesian approach

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HIGHLIGHTS

- We investigate the nature of the volatility of EUA futures prices.
- The MCMC estimation reveals that the EUA volatility evolves stochastically over time.
- Jumps in returns and volatility are especially pronounced at around the beginning of Phase III.

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ABSTRACT

Understanding the stochastic nature of the spot volatility of emission allowances is crucial for risk management in emissions markets. In this study, by adopting a stochastic volatility model with or without jumps to represent the dynamics of European Union Allowances (EUA) futures prices, we estimate the daily volatilities and model parameters by using the Markov Chain Monte Carlo method for stochastic volatility (SV), stochastic volatility with return jumps (SVJ) and stochastic volatility with correlated jumps (SVCJ) models. Our empirical results reveal three important features of emissions markets. First, the data presented herein suggest that EUA futures prices exhibit significant stochastic volatility. Second, the leverage effect is noticeable regardless of whether or not jumps are included. Third, the inclusion of jumps has a significant impact on the estimation of the volatility dynamics. Finally, the market becomes very volatile and large jumps occur at the beginning of a new phase. These findings are important for policy makers and regulators.

1. Introduction

The recent development of financial engineering has made it possible for nations around the world to devise financial derivatives as part of an attempt to solve environmental problems such as air pollution and global warming. The emissions trading scheme (ETS) is one such attempt to alleviate the air pollution caused by the emission of greenhouse gases via a financial market mechanism. Under the ETS, the right to emit greenhouse gases becomes a tradable asset, whose price can help to control the excessive emission of greenhouse gases through a self-regulating mechanism.

Specifically, the general structure of the ETS is as follows. The total number of allowances (or caps) is determined by a national policy designed to reduce gas emissions, or so-called National Allocation Plan. Given a total cap on a given emission in a nation, the allowances are distributed by authorities to firms in industries intensively emitting greenhouse gases.[1] At the

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1 One share of allowance permits one ton of emission in the European market.

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end of a period (or so-called phase), firms must buy emission allowances if their emissions of these greenhouse gases exceed the cap allocated at its beginning. On the other hand, those firms who manage to keep their emissions below the cap, such as by devising a fuel-efficient system, can sell their residual allowances in the emissions trading market through a process which is referred to as the "cap-and-trade" system. Under this system, the supply and demand for allowances determine the market price, and the market participants try to significantly reduce their emissions. In this way, they can make profits for themselves by selling the unneeded residuals. The CO_2 emission allowances of the European Union Emissions Trading Scheme (EU-ETS) constitute the best example of the cap-and-trade system of emission trading markets.

Understanding the stochastic properties of spot volatility is of importance for risk management in the emissions market. While the effectiveness of stochastic volatility models (with or without jumps) has been advocated by academics and practitioners in the equities market, few attempts have been made to apply them to the newly-developed commodities market governing CO_2 emission allowances. In order to investigate the volatility dynamics of the (spot or futures) prices of emission allowances, we estimate Heston [1]'s stochastic volatility model with or without jumps. In doing so, the Monte Carlo Markov Chain (MCMC) method, a Bayesian approach, is employed. To the best of our knowledge, this study is the first to employ the MCMC method to estimate the stochastic volatility of emission allowances. Under the cap-and-trade system, emission allowances become tradable financial assets. As in typical studies in other commodity markets, the European Union Allowances (EUA) spot and futures prices can be investigated by the traditional models employed in financial economics.

Several studies have attempted to examine the spot prices of the CO_2 emission allowances of the EU-ETS by using econometric approaches. For example, Paolella and Taschini [2] suggested using econometric frameworks to explain the unconditional tail behavior and heteroskedastic dynamics of the returns of CO_2 emission allowances. They attributed the poor performance of previous approaches, such as the analysis of forecasting factors including demand/supply fundamentals or futures/spot parity analysis, to the complexity of the market and uniqueness of the asset process. For this reason, they supported the employment of GARCH-type structural models, which are suitable for depicting the stylized facts of return series. Seifert et al. [3] also analyzed the price dynamics of CO_2 spot prices based on their own tractable stochastic equilibrium model, which reflects the unique characteristics of the EU-ETS; in particular, its banking and borrowing regulations are substantially different from those of other emissions markets. They found that CO_2 spot prices follow a martingale process and exhibit a time- and price-dependent volatility structure. Similarly, Chesney and Taschini [4] developed an endogenous model to capture the potential presence of asymmetric information among market players regarding net permits in the European market, while Benz and Trück [5] examined the short-term spot prices of over-the-counter CO_2 emission allowances and employed a regime-switching model to describe the heteroskedastic behavior of returns.

While previous authors have proposed appropriate models to describe the spot price of carbon emission allowances, no consistent conclusion has yet been made regarding the most adequate pricing model for carbon derivatives, because of the complications caused by the distinct phases and specific regulations inherent in the EU-ETS. For instance, Uhrig-Homburg and Wagner [6] found supportive evidence for a cost-of-carry pricing mechanism by analyzing carbon futures that mature during Phase I. By contrast, according to Borak et al. [7], the carbon futures that were issued during Phase I and matured during Phase II have significant convenience yields. Further, by analyzing the spots and futures traded within the EU-ETS, Daskalakis and Markellos [8] showed that the European market for CO_2 emission allowances is inefficient.

The authors attributed this market inefficiency to the immaturity of the EU-ETS, restrictions on short selling, and prohibition of banking. Daskalakis et al. [9] claimed that the proscription of banking, which implies that emission allowances become worthless at the end of each phase, plays an important role in determining the prices of EUA futures. In particular, the prices of intra-phase contracts can be explained by the cost-of-carry model with zero convenience yield, while those of inter-phase futures need to be examined by a cost-of-carry model with stochastic, mean-reverting convenience yield. The authors also showed that models considering jumps or a stochastic convenience yield are better at pricing intra-phase and inter-phase options on futures than simple models, such as that proposed by Black [10], in terms of their ability to fit out of sample data.

However, previous studies never focused on the impact of jumps in returns and volatility. Motivated by the inconsistency and shortcomings of previous studies on carbon derivatives, we estimate futures price dynamics based on Heston's SV model with or without jumps. This estimation is conducted by the MCMC (Markov Chain Monte Carlo) method in an attempt to explain the price dynamics of carbon futures traded in the EU-ETS.

Another contribution of this study is an empirical analysis of the maturity of carbon futures during Phase III, which has rarely been covered in previous studies. As mentioned earlier, the total supply of allowances relative to the demand for their emission in the market determines their price in the cap-and-trade system. During Phase I, a trial period, the transfer of residual allowances to Phase II was prohibited. Thus, over-allocated allowances became worthless at the end of the period. Unfortunately, it was revealed that the total supply in the trial period exceeded the total demand; the emissions were much less than expected. Subsequently, the EUA futures prices experienced a sudden drop because of the prohibition of banking. To address this issue, during Phase II, the banking of EUAs is permitted in the years within this period, as well as over to the next period, Phase III. For this reason, investigating the price dynamics of EUA spot and futures entering into Phase III is of crucial importance. Therefore, our study includes intra- and inter-phase examinations.

In addition, during Phase II (the trading period of the EUA futures maturing during Phase III), the European market experienced a debt crisis originating from Greece, which caused the European economy to become sluggish and, subsequently, the total emissions to be reduced. During the trial period, Phase I, the market already experienced excess supply, but this is a different case in that banking is not permitted at that time. Given that allowances can be banked from

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