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Modeling EU allowances and oil market interdependence. Implications for portfolio management

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ABSTRACT

This paper examines the dependence structure between European Union allowances (EUAs) and crude oil markets during the second commitment period of the European Union Emissions Trading Scheme and the implications for portfolio management. Using different copula models, our findings suggest positive average dependence and extreme symmetric independence that is consistent with interdependence and no contagion effects between the EUA and crude oil markets. The implication of this result for EUA-oil portfolios points to the existence of diversification benefits, hedging effectiveness, and value-at-risk reductions. The EUA market is therefore an attractive market for investors in terms of diversifying market risk and reducing downside risk in crude oil markets.

1. Introduction

After implementation of the European Union (EU) Emissions Trading System (EU ETS) in January 2005, EU Allowances (EUAs) became a tradeable asset that could be negotiated in organized spot, futures and options markets. Under the new cap-and-trade paradigm, the EUA market has witnessed rapid development and is steadily increasing in size, complexity, liquidity and trading volume. This has greatly spurred research into allowance allocations and pricing mechanisms in the European carbon market, of primary interest to policy makers, traders and risk managers operating in this and related markets. One strand of the literature analyzes the price dynamics of different EU ETS instruments on a daily or intraday basis (Benz and Trück, 2009; Chevallier, 2009a; Conrad et al., 2012; Daskalakis et al., 2009; Paolella and Taschini, 2008), price efficiency and information transmission between EU carbon spot and futures markets (Benz and Hengelbrock, 2008; Chevallier, 2010; Milunovich and Joyeux, 2010; Rittler, 2012; Uhrig-Homburg and Wagner, 2009) and the impact of the EU ETS on the financial markets (Daskalakis and Markellos, 2009; Oberndorfer, 2009; Veith et al., 2009). Another strand has explored the potential drivers of carbon price changes (Alberola et al., 2008; Bredin and Muckley, 2011; Christiansen et al., 2005; Convery and Redmond, 2007; Kanen, 2006; Mansanet-Bataller et al., 2007; Redmond and Convery, 2006), finding that carbon prices are closely linked to exceptional weather conditions, economic growth and energy prices.[1]

Despite the fact that carbon prices were found to be closely associated with oil prices at the theoretical and empirical level (see Kanen, 2006; Redmond and Convery, 2006) and that both EUAs and crude oil are negotiated in well-developed spot and futures markets, no study has yet examined the cross-market linkages between these two commodities. The main objective of our study, therefore, was to analyze the EUA and crude oil market dependence structure using copulas, a methodology that allows greater flexibility in modeling dependence than parametric bivariate distributions and, more interestingly, that enables us to determine whether EUA-oil markets are somewhat dependent or independent on average or in times of market stress on the basis of their tail dependence. Although oil and carbon prices are theoretically linked through the effects of oil price changes on natural gas and electricity price movements, how EUA prices react to extreme oil price market movements and vice versa is an empirical issue that needs to be addressed. In addition,

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[1] Zhang and Wei (2010) provide a recent extensive survey on current research into the EU ETS.

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understanding how EUA and crude oil markets co-move is essential information for optimal portfolio design and risk management decision making by investors and traders operating in those markets. We thus investigated the implications of EUA-oil market average and tail dependence for portfolio management by analyzing optimal portfolio weights and hedge ratios for EUA-oil portfolio holdings compared to simple oil stock portfolios. Likewise, we evaluated whether an investor could achieve downside risk gains from a portfolio composed of crude oil and by EUAs analyzing the value-at-risk (VaR) performance.

Our empirical study was conducted from the onset of Phase II of the EU ETS in 2008, as it was in this phase that a more stable relationship was configured between the EUA system and its determinants (Bredin and Muckley, 2011) and market liquidity in EUA futures markets experienced a significant rise (Benz and Hengelbrock, 2009; Bredin et al., 2009). By analyzing daily data for EUA futures contracts and crude oil prices, our study makes two major contributions to the empirical literature on modeling carbon emissions. Firstly, our paper is the first study we are aware of that investigates the interdependence of EUA and crude oil markets using copulas and that provides empirical evidence of positive average dependence and extreme symmetric market independence between EUA and crude oil prices, with the Gaussian copula as the best performing dependence model. This evidence is consistent with no contagion effects between EUA and crude oil markets. Secondly, we address the consequences of EUA and crude oil market links for portfolio management and provide evidence of the usefulness of EUA stocks in a crude oil portfolio, given that they increase the risk-adjusted portfolio returns, show evidence of hedging effectiveness in reducing portfolio risk and, finally, show a significant VaR reduction and better performance in terms of the investor's loss function with respect to a portfolio composed only of crude oil assets. On the basis of these results, the EUA market is an attractive financial market for investors wanting to avoid market risk in crude oil markets.

The rest of the paper is laid out as follows: Section 2 provides a brief overview of the EU ETS. In Section 3, we outline the methodology we used to study EUA-oil interdependence. Sections 4 and 5 present data and results, respectively, and Sections 6 and 7 discuss the portfolio implications of our dependence results and provides our conclusions, respectively.

2. The European Union Emissions Trading System

The EU ETS was formally introduced in January 2005 with the purpose of encouraging reductions in greenhouse gas emissions in a cost-effective way. The EU and its member states agreed to construct a market for trading carbon emission allowances in which four industrial sectors are required to participate, namely, energy, ferrous metal production and processing, minerals and other energy-intensive sectors. One EUA grants its holder the right to emit one metric ton of CO_2-equivalent (tCOEe) during a specified commitment phase. The EU ETS is organized in three commitment phases. The initial pilot period, Phase I, lasted from 2005 to 2007; the second period, Phase II, lasting from 2008 to 2012, coincides with the first Kyoto protocol commitment to reduce EU greenhouse gas emissions by 8% below the 1990 level; and the third period, Phase III, will run from 2013 to 2020.

The market is structured on the basis of a cap-and-trade system, whereby each state receives a certain volume of EUAs to meet compliance requirements, as determined by a National Allocation Plan (NAP). The NAPs, defined by each member state and published by the European Commission, list the totals assigned to each country and the rules for distribution among participating firms. Once allowances have been allocated, firms can either consume their stock of EUAs (i.e., emit CO_2) or abate emissions and sell their surplus EUA units in the market. On 30 April each year, the participating firms are required to verify their emissions and provide the equivalent quantity of EUAs to a national competent authority. Firms without EUAs purchase them from other firms or market participants and firms with spare units sell them on the market. To meet compliance requirements, firms may also use other instruments, called Certified Emission Reductions (CERs) – obtained on the basis of emission reduction projects and with a use limit of 13.8% – or Emission Reduction Units (ERUs) – obtained by reducing emissions under Joint Implementation (JI) projects. If emissions are not covered by EUAs or the other instruments, firms are fined 40 Euros/tCOEe (in Phase I) or 100 Euros/tCO2e (in Phase II).

Allowances are traded in both organized and over-the-counter markets. Trading is regulated by each member state and supervised by national authorities. The most liquid EUA spot market is BlueNext in Paris, accounting for about 70% of the total daily turnover in organized markets. The most liquid futures market is ICE in London, which attracts about 90% of the daily turnover in EUA futures.

3. Methodology

The analysis of cross-market linkages between the EUA and crude oil markets requires knowledge of the dependence structure between these two markets. Dependence can be measured in several ways from information contained in the joint distribution of the EU ETS and crude oil markets, for example, in terms of average movements across marginals or of joint extreme movements. Instead of using a specific parametric joint density, in this paper we used copulas to flexibly model the joint distribution.

A copula[2] is a flexible representation of the dependence structure that connects margins to a multivariate distribution function. Sklar's theorem (1959) states that the joint distribution of two continuous random variables X and Y, $F_{XY}(\mathrm{x,y})$, with marginal functions $F_X(\mathrm{x})$ and $F_Y(\mathrm{y})$, is characterized by a copula function C such that:

$$F_{XY}(\mathrm{x},\mathrm{y}) = C(F_X(\mathrm{x}), F_Y(\mathrm{y})). \tag{1}$$

Thus, a multivariate distribution function can be decomposed into its univariate marginal distributions and a copula that captures the dependence structure between the two variables. In fact, the copula is a multivariate distribution function that relates the quantiles of the marginal distributions, $u = F_X(\mathrm{x})$ and $v = F_Y(\mathrm{y})$, rather than the original variables. Hence, the copula is unaffected by monotonically increasing transformation of the variables.

The conditional copula function which relaxes the i.i.d. assumption, introduced in the finance literature by Patton (2006), is given by:

$$F_{XY|W}(\mathrm{x},\mathrm{y}|\mathrm{w}) = C\left(F_{X|W}(\mathrm{x}|\mathrm{w}), F_{Y|W}(\mathrm{y}|\mathrm{w})|\mathrm{w}\right), \tag{2}$$

where W is the conditioning variable, $F_{X|W}(\mathrm{x}|\mathrm{w})$ is the conditional distribution of $X|W = \mathrm{w}$, $F_{Y|W}(\mathrm{y}|\mathrm{w})$ is the conditional distribution of $Y|W = \mathrm{w}$ and $F_{XY|W}(\mathrm{x,y}|\mathrm{w})$ is the joint conditional distribution of $(X,Y)|W = \mathrm{w}$.

The joint density is obtained by differentiating Eqs. (1) and (2); hence:

$$\begin{aligned} f_{XY}(\mathrm{x},\mathrm{y}) &= f_X(\mathrm{x}) \cdot f_Y(\mathrm{y}) \cdot c(u,v), \\ f_{XY|W}(\mathrm{x},\mathrm{y}|\mathrm{w}) &= f_{X|W}(\mathrm{x}|\mathrm{w}) \cdot f_{Y|W}(\mathrm{y}|\mathrm{w}) \cdot c(u,v|\mathrm{w}), \end{aligned} \tag{3}$$

where $c(u,v) = \partial^2 C(u,v)/\partial u \partial v$ and $c(u,v|w) = \partial^2 C(u,v|w)/\partial u \partial v$ are the unconditional and conditional copula densities, respectively. Consequently, the unconditional (conditional) joint density of the variables X and Y is represented by the product of the unconditional (conditional) copula density and the two (conditional) marginal densities.

[2] For an introduction to copulas, see Joe (1997) and Nelsen (2006).