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Is there dependence and systemic risk between oil and renewable energy stock prices?

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ABSTRACT

We study systemic risk and dependence between oil and renewable energy markets using copulas to characterize the dependence structure and to compute the conditional value-at-risk as a measure of systemic risk. We found significant time-varying average and symmetric tail dependence between oil returns and several global and sectoral renewable energy indices. Our evidence on systemic risk indicates that oil price dynamics significantly contributes around 30% to downside and upside risk of renewable energy companies. These results have important implications for risk management and renewable energy policies.

1. Introduction

Oil price dynamics impact on the performance of renewable energy companies by making the substitution of exhaustible energy resources with sustainable energy resources more or less profitable (see, e.g., Kumar et al., 2012). Identifying how oil price dynamics affect the performance of renewable energy firms is useful for investors who need to know whether an investment in renewable energy stocks is more or less attractive when oil prices are high or low; in particular, investors need to assess the potential downside or upside risks arising from extreme oil price movements. Policy makers also need to better understand how oil prices impact on the renewable energy industry, given that public expenditure aimed at progressively reducing dependence on finite fossil fuels and carbon dioxide emissions could be reduced when oil price dynamics provide the necessary supply- or demand-side incentives to invest in the renewable energy industry. Hence, understanding how fossil fuel prices co-move with clean energy stock prices is an important issue of concern to investors and policy makers in equal measure.

Previous empirical studies have examined the effect of oil prices on the financial performance of renewable energy companies. Henriques and Sadorsky (2008) reported evidence of Granger causality from crude oil prices to stock prices for renewable energy companies listed on major US stock exchanges. Sadorsky (2012a) provided evidence of volatility spillovers between oil prices and alternative energy stocks, whereas Sadorsky (2012b) showed that a rise in oil prices has a positive impact on the beta of renewable energy stocks. Wen et al. (2014) documented mean and volatility spillover effects between Chinese renewable energy and fossil fuel companies. Kumar et al. (2012) showed that rising oil prices, unlike carbon prices, significantly impact on renewable energy stock prices. Using different econometric approaches, all of the above-mentioned studies provide evidence of average dependence between oil and renewable energy stock prices. However, no study to date, paying specific attention to tail dependence and the possible systemic impact of oil prices changes on renewable energy stocks, has analysed how oil and renewable energy stock prices co-move. This paper attempts to fill this gap, contributing to the existing literature in three ways.

First, using copulas — a statistical tool that provides information on average and upper and lower tail dependence (joint extreme movements) — we study the dependence structure between crude oil and clean energy stock prices. The information yielded by copula functions enables us to determine whether crude oil and clean energy markets are somewhat dependent or independent, whether extremely high or low oil prices are symmetrically or asymmetrically dependent on renewable energy stock prices and whether dependence has changed in recent years as the result of growing investment in the renewable energies sector. This

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detailed information on dependence helps to clarify whether market-based or policy-oriented incentive mechanisms or a mixture of both should be deployed to foster the development of renewable energies.

Second, we analyse the implications of co-movement between crude oil and clean energy stock prices for the systemic risk of oil prices on renewable energy stock prices, using the conditional value-at-risk (CoVaR) systemic risk measure, as proposed by Adrian and Brunnermeier (2011) and generalized by Girardi and Ergün (2013). The CoVaR captures risk spillovers of oil prices measured as the value-at-risk (VaR) of an investment in renewable energy stocks conditional on the fact that oil markets experience an extreme price movement. The CoVaR thus provides quantitative evidence regarding the impact of extremely high or low oil prices on renewable energy stock prices; the systemic risk contribution of oil prices to renewable energy prices, systemic risk changes over time and, finally, the symmetric or asymmetric systemic risk impact of oil price movements. Measuring systemic risk for renewable energy stock investments is crucially important for an optimal portfolio strategy when investors have a utility function characterized by minimized CoVaR, as more emphasis is placed on minimizing this type of risk than when the focus is on reducing portfolio variance (see e.g., Low et al., 2013). In addition, accounting for systemic risk is critical for the design of optimal portfolio investment strategies since this kind of risk impacts on the gains from diversification, with potential jumps in systemic risk more likely to change optimal portfolio weights. Finally, the presence of systemic risk penalizes renewable energy investors that leverage new energy stock positions by increasing unexpected tail losses (see e.g., Das and Uppal, 2004).

Third, for the period December 2005 to December 2013, for three global renewable energy stock price indices (the S&P Global Clean Energy Index, the Wilder Hill Clean Energy Index and the European Renewable Energy Index) and three clean energy sectoral indices (the NYSE Bloomberg Global Wind, Solar Energy and Smart Technologies indices), we provide evidence of time-varying positive average dependence and symmetric tail dependence (for all the indices with the exception of the solar energy index, where tail dependence was asymmetric) that is consistent with the idea that oil and renewable energy markets are coupled. In this context, market-oriented incentives to encourage development of the renewable energy sector are effective when oil prices are high, as the economic viability of renewable energy projects is enhanced; however, low oil prices discourage renewable energy investments and reduce the value of renewable energy companies. Hence, policy-oriented strategies aimed at facilitating the transition to a sustainable energy system should take into account this effect and should be implemented asymmetrically — that is, reinforced when oil prices are low and relaxed when oil prices are high — given that market-oriented incentives will be weak and strong, respectively. On the other hand, our systemic risk analysis indicated that oil prices significantly contribute to the systemic risk of renewable energy companies. Furthermore, the CoVaR values were symmetric for all the renewable energy indices, with the exception of the solar energy index, and also display consistent temporal patterns, pointing to more systemic risk after the onset of the recent global financial crisis. This would indicate that renewable energy investors should pay special attention to the potential downside or upside risk effects of oil price movements.

The remainder of the paper is laid out as follows. In Section 2 we review previous empirical research into the link between oil and clean energy stock prices. In Section 3 we describe the methodological approach underlying the research into dependence and systemic risk between crude oil prices and renewable energy stock prices. In Section 4, we describe the main features of our data. In Section 5 we discuss our results and their main implications. Finally, Section 6 summarizes our results and concludes the paper.

2. Literature review

The effect of oil prices on stock prices has been well documented in the empirical literature, given that an oil price shock may, depending on the degree of oil dependence, positively or negatively impact a firm's future cash flow and cash flow discount factors, in accordance with the effects of an oil price shock on macroeconomic factors, in particular, inflation and interest rates. The extant empirical evidence is mixed, finding positive, negative and even null effects of oil prices on stock markets.[1] The paradox, in considering alternative energy stocks, is that the oil price plays a central role in determining the profitability of renewable energy projects, by incentivizing or discouraging the use of alternative energies (depending on the economic point of view). Despite the importance of oil prices in determining alternative energy stock prices and the investment profitability of renewable energy companies, relatively few empirical studies have examined the relationship between oil and renewable energy stock values and their implications. Below we summarize the main features of the literature that does exist.

Henriques and Sadorsky (2008) employed a vector autoregressive model to account for the relationship between oil prices, alternative energy stock prices, technology stock prices and interest rates for the period January 2001 to May 2007, finding Granger causality from crude oil price to stock prices of alternative energy companies. They also found that the behaviour of renewable energy stock prices closely mirrored those of technology stock prices. The vector autoregressive analysis performed by Henriques and Sadorsky was extended by Managi and Okimoto (2013), who considered Markov-switching effects in order to account for possible structural changes in the oil-renewable energy stock price relationship; they found a structural break in late 2007, before which oil prices had no effect on clean energy stock prices and after which considerably higher oil prices had a positive impact.

Kumar et al. (2012) also used a vector autoregressive approach but considered an additional variable, namely, prices for carbon allowances traded in the European Emissions Trading System. Their evidence for weekly data from April 2005 to November 2008 indicated clean energy stock prices to be affected by oil prices, interest rates and technology stock prices; however, carbon allowance prices had no significant effects on the renewable energy stock prices. Similarly, for Chinese energy-related stocks, Broadstock et al. (2012) showed that oil price dynamics impacted on energy stocks in China, especially after the onset of the recent global financial crisis, when correlation increased significantly.

Using a multivariate generalized autoregressive conditional heteroskedasticity (GARCH) model, Sadorsky (2012a) studied volatility spillovers between oil prices and clean energy stock prices and conditional correlations, finding that renewable energy stock prices correlated more intensively with technology stock prices than with oil prices, and that oil was a useful hedge for clean energy stocks. Wen et al. (2014) also studied the return and volatility spillover effects between Chinese renewable energy stock prices and fossil fuel stocks using daily data and an asymmetric Baba–Engle–Kraft–Kroner (BEKK) model, finding that renewable energy and fossil fuel stocks were competing assets, with significant mean and volatility spillovers between them even though renewable energy stocks were riskier than fossil fuel stocks.

Sadorsky (2012b) examined the determinants of renewable energy company risk using a variable beta model, finding that oil price positively increased impact company risk, even though this effect was modulated by company sales growth behaviour. Ortas and Moneva (2013) studied the time-varying beta behaviour of clean-technology equity indices, finding that these indices yielded higher returns and risk than conventional stock indices.

Other studies have examined the factors that drive renewable energy stock performance. Bohl et al. (2013) studied the behaviour of German renewable energy stocks, finding that they exhibited substantial systematic risk and were subject to speculative attacks that generated speculative bubbles before the onset of the global financial and European sovereign debt crises. Ferstl et al. (2012) examined the impact

[1] For a survey of this literature, see Reboredo and Rivera-Castro (2014).