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Wavelet-based test of co-movement and causality between oil and renewable energy stock prices

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ABSTRACT

We studied co-movement and causality between oil and renewable energy stock prices using continuous and discrete wavelets, firstly, to obtain information on dynamic correlations over time and for different time scales from wavelet coherence and, secondly, to obtain information on linear and non-linear Granger causality in the time-frequency domain. For general and sectoral renewable energy indices for the period 2006–2015, our findings indicate that dependence between oil and renewable energy returns in the short run was weak but gradually strengthened towards the long run, mainly for the period 2008–2012. Our causality tests provide evidence against linear causality at higher frequencies and in favour of unidirectional and bidirectional linear causality at lower frequencies. In contrast, we found consistent evidence of non-linear causality running from renewable energy indices to oil prices at different time horizons and mixed evidence of causality running from oil to renewable energy prices. These results have potential implications for investors in terms of hedging and for policymakers in terms of policy support decisions regarding the development of renewable energy.

1. Introduction

Growing environmental concerns about climate change and costly fossil fuels have spurred the development of the renewable energy sector as arguably the best way to address the challenges of climate change and to switch to sustainable energy supply systems (Aguirre and Ibikunle, 2014; Cadoret and Padovano, 2016). Although a growing number of countries have implemented a wide range of policy instruments to foster renewable energies (e.g.,Kitzing et al., 2012), renewable energy companies must be profitable so as to attract private capital reallocation to new energy investments and thus enable long-run policy objectives to be met.

Oil prices, as one of the main determinants of the profitability of renewable energy projects, make the substitution of exhaustible energy resources with sustainable energy resources more or less profitable (see, e.g., Kumar et al., 2012; Reboredo, 2015). Likewise, the economic success of new energy projects also influences energy supply and oil demand and ultimately affects oil prices. Therefore, as long as oil and new energy stock markets are intrinsically related, identifying dependence and causal effects between oil price dynamics and renewable energy returns at different time scales – the short and long run in particular – is useful for investors with different time horizons for their strategic investment decisions. Moreover, dependence and causality between oil prices and renewable energy returns is also of interest for policymakers, as oil prices could provide adequate supply- or demand-side incentives to invest in renewable energy in the short- or long-run, thereby determining the quantity and timing of public expenditure deployed to support new energy.

In this paper we examine, using wavelets and linear and non-linear Granger causality tests, the dependence and direction of causality between oil and renewable energy stock returns at different time scales. Although previous empirical studies (see literature review below) have reported evidence on dependence and causality between oil and new energy stock returns for single time scales, little is known regarding dependence and causality at different time scales. To fill this gap, we examined how dependence between oil and new energy stock returns changed over time and differed across

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time scales, focusing in particular on dynamic correlations based on wavelet coherence. We also examined the direction of causality between oil and renewable energy stock returns for different time horizons using linear and non-linear Granger causality tests as proposed by Hiemstra and Jones (1994) and later modified by Diks and Panchenko (2006).

Our empirical analysis, conducted for the period January 2006 to March 2015, considered three renewable energy indices (the Wilder Hill Clean Energy Index, the S&P Global Clean Energy Index and the European Renewable Energy Index), three renewable energy sectoral indices (the NYSE Bloomberg Global Wind, Solar Energy and Smart Technologies indices) and prices for West Texas Intermediate (WTI) oil. Our empirical evidence indicates that the dynamic interaction between oil prices and renewable energy returns was weak in the short run but gradually increased over the long run, although differences were observed between general and sectoral indices and between different time periods. Regarding causality, our results indicate that there is no linear causality at higher frequencies, whereas there is evidence of unidirectional and bidirectional linear causality, depending on the time scale, at lower frequencies. We also found evidence of non-linear causality at both low and high frequencies. Our results have practical implications for policymakers and investors operating with different investment horizons in these markets, as they need horizon-specific information on dependence and causality for their diversification and hedging strategies and for value-at-risk computation. More specifically, independence and non-causality at the higher frequencies means that investors could use oil as a hedge for renewable energy investments but not to forecast renewable energy stock returns. Furthermore, over the long run, investors – although unable to take advantage in terms of hedging – could benefit from the forecasting ability of oil and renewable stock returns. Likewise, the absence of causality and linear dependence in the short run means that oil price behaviour provides no incentive to increase renewable energy investment; over the long run, however, since the oil and renewable energy markets are coupled, high oil prices would enhance the economic viability of renewable energy projects, whereas low oil prices would reduce the value of renewable energy companies. All of this implies that policymakers should dedicate greater efforts to promoting short-run development of renewables. In the long-run, however, efforts should be reinforced when oil prices are low and relaxed when oil prices are high.

The rest of the paper is organized as follows. In Section 2, we review previous empirical studies on the relationship between oil and renewable energy stock prices. In Section 3, we describe the wavelet approach and the linear and non-linear Granger causality tests underpinning our research into dependence and causality between oil and renewable energy stock returns. In Section 4, we describe the main features of the data. In Section 5, we present our results on dynamic dependence and causality at different time scales and discuss their main implications. Finally, Section 6 summarizes our results and concludes the paper.

2. Literature review

Previous empirical studies have examined the impact of oil prices on renewable energy markets, finding evidence of causality, dependence and volatility spillovers. Henriques and Sadorsky (2008) found evidence of linear Granger causality from crude oil to renewable energy stock prices. However, Managi and Okimoto (2013) provided evidence of a structural change in causality, finding that oil prices had no effect on clean energy stock prices before late 2007, but thereafter had a positive impact. Considering the prices of carbon allowances traded in the European Emissions Trading System, Kumar et al. (2012) reported that rising oil prices, interest rates and technology stock prices, unlike carbon prices, had a positive impact on clean energy stock prices. Likewise, Broadstock et al. (2012) showed that oil price dynamics significantly impacted on new energy stocks in China, particularly after the onset of the global financial crisis, when dependence increased noticeably. More recently, Reboredo (2015) reported evidence of time-varying average and symmetric tail dependence between oil prices and a set of global and sectoral renewable energy indices. Examining the dynamics of excess returns for the Wilder Hill New Energy Global Innovation Index, Inchauspe et al. (2015) found that the price of oil was an influential pricing factor, mainly after 2007, although it played a minor role in comparison with the MSCI World index and technology stocks.

Another strand of the literature has examined volatility spillovers between oil prices and clean energy stock prices. Sadorsky (2012a) found not only that oil prices have volatility spillover effects on clean energy stock prices but also that oil was a useful hedge for clean energy stocks; however, dependence between renewable energy stock prices with technology stock prices was higher than with oil prices. Similarly, using a variable beta model to study the determinants of renewable energy company risk, Sadorsky (2012b) reported that oil prices had a positive influence on this risk. For Chinese renewable energy and fossil fuel stock prices, Wen et al. (2014) reported evidence of significant mean and volatility spillovers between renewable energy and fossil fuel stocks, with renewable energy stocks carrying more risk than fossil fuel stocks. More recently, Reboredo (2015) found that oil price dynamics significantly contributes around 30% to downside and upside risk for renewable energy companies.

Our study contributes to the extant literature on the relationship between oil and new energy stock markets by providing solid evidence of dependence and linear and non-linear causality between oil price variations and renewable energy stock returns at different time scales. More specifically, we use discrete and continuous wavelets to study frequency components of oil and renewable stock time series without losing time domain information and without assuming specific parametric models to account for features – such as time-dependent volatility, covariance and structural breaks – that are pervasive in financial time series. Although wavelets have been previously used to study dependence among energy assets and between energy assets and other financial variables (see, e.g., Naccache, 2011; Vacha and Barunik, 2012; Vacha et al., 2013; Jammazi, 2012; Reboredo and Rivera-Castro, 2013; Reboredo and Rivera-Castro, 2014; Madaleno and Pinho, 2014; Alzahrani et al., 2014), no study has, as yet and as far as we are aware, accounted (1) for causality between oil and new energy returns combining (discrete) wavelet methods with linear and non-linear causality tests or (2) for dynamic dependence between oil and new energy returns across time scales using cross-wavelet coherence and phase analysis.

3. Methodology

We use continuous wavelets and cross-wavelet transforms to show how the local variance and covariance of two time series evolve, and wavelet coherence and phase analysis to measure local co-movement between two time series in the time-frequency domain.[1] Furthermore, we use discrete wavelets to explore the linear and non-linear causality relations between oil and renewable energy returns at different time horizons. In the following sections we briefly describe core wavelet concepts and the linear and non-linear Granger causality tests used for this research.

[1] A detailed analysis of wavelet methods can be found in Gençay et al. (2002), Percival and Walden (2000), Serroukh et al. (2000), Torrence and Compo (1998), Whitcher et al. (2000) and Gençay et al. (2005).