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Correlations between oil and stock markets: A wavelet-based approach☆

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ABSTRACT

In a global economy, shocks occurring in one market can spill over to other markets. This paper investigates the impact of oil shocks and stock market crashes on correlations between stock and oil markets. We test changes in correlations for different time scales with non-overlapping confidence intervals based on estimated wavelet correlations. Our results indicate that correlation between oil and stock markets tends to be stable in non-shock periods, around zero, but this changes during oil and financial shocks both at higher and lower frequencies. We find evidence of contagion, in particular during the 2008 and 2011 stock market falls. At low frequencies, the number of correlation breakdowns during oil shocks and stock market crashes is higher and they can be interpreted as shifts in market co-movements.

1. Introduction

The keystone of both portfolio allocation and risk management decisions is the correlation structure of asset returns. Therefore, understanding the dynamics of correlations remains an important task not only for financial research but also for applications in the financial industry.

The time-varying nature of correlations has been widely documented (see e.g. Cai et al., 2009; De Santis and Gerard, 1997; Longin and Solnik, 1995, 2001) and stock market crashes or currency crises seem to impact the correlations between international stock markets. Crashes can create contagion in many markets, increasing correlation between them over very short periods of time. Yet, they can also contribute to greater market integration by increasing the interdependence or co-movements between markets over longer periods of time (see Bodart and Candelon, 2009; Gallegati, 2012; Reboredo and Rivera-Castro, 2014).

Recent work has used a frequency domain approach to study this issue where each frequency corresponds to a particular component of the variable. Bodart and Candelon (2009) use the framework of a Vector Autoregressive (VAR) model and propose a contagion test based on a causality measure applied at different frequencies. Orlov (2009) uses the finite Fourier transform without assuming any model for the data. Fourier's analysis decomposes the covariance into different frequency levels. Contagion is estimated as the change of the high-frequency components of the covariance between crisis and non-crisis periods. Gallegati (2012) advocates the use of the multi-resolution decomposition property of the wavelet transform to identify contagion and interdependence separately by associating each with its corresponding frequency components. He proposes using the information of the high frequency part to test for contagion, and low frequency components to analyze interdependence. Finally, Ftiti et al. (2014) use evolutionary cospetral analysis (Priestley and Tong, 1973) and wavelets to analyze the co-movements dynamics between OCDE countries, the U.S. and Europe. They find that these two sophisticated techniques are both powerful in distinguishing between contagion and interdependence and especially in accessing co-movements between time series regarding time and frequency.

This study focuses on oil and stock market shocks and on their impact on the correlation structure between oil and stock markets. Oil is a crucial input in economic activity, and consequently oil price increases are a hindrance to economic growth. Stock markets, as recognized bellwethers of the economy (see e.g. Fama, 1990; Fama and

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French, 1989; Schwert, 1990), anticipate the fall in corporate cash flow and adjust firm value. Since each country's degree of oil dependence is different, the impact of oil price increases depends on national oil level dependence (Ramos and Veiga, 2013). Therefore, changes in stock market valuation differ between countries, changing correlation within markets.

Recently, the financialization of commodity markets has strengthened the links between oil and stock markets. Including commodities as an asset class in portfolios has expanded, backed by innovation in derivative securities. Many argue that with the opening of commodity markets to financial investors, commodity markets become increasingly driven by flows of financial investors and less by their fundamentals, strengthening the links between these markets.[1] Empirical evidence has documented an increase in correlation between commodity and equity markets (see e.g., Büyüksahin and Robe, 2014; Silvennoinen and Thorp, 2013).

Given the links between markets, we posit that price disruptions in one market are likely to affect other markets and we investigate whether oil price shocks and stock market crashes have an impact on stock market and oil market correlations. Note that the focus of our work is on whether the correlation between those markets changes and not on the direct impact of oil shocks in stock market returns (see e.g. Driesprong et al., 2008; Chen et al., 1986; Huang et al., 1996; Jones and Kaul, 1996; Kilian and Park, 2009; Narayan and Sharma, 2011; Narayan and Gupta, 2015; Ramos and Veiga, 2013).

To analyze this issue, we follow the framework of Gallegati (2012) that uses wavelets[2] to distinguish between contagion and interdependence. He uses information of the high frequency part to test for contagion, and low frequency components to analyze interdependence. The tests are graphical, based on non-overlapping confidence intervals of estimated wavelet coefficients calculated in shock and non-shock periods. We present the results with a new visualization tool, where the confidence intervals of different periods are shown above the time line. The plot easily represents changes in correlation over time by visually checking the overlap between two consecutive periods. Other advantages of the wavelets methodology are its ability to handle irregular data without imposing any functional form, to decompose the series by time scale so as to capture relationships between variables that may differ across time-scales, to detect sudden regime changes and isolated shocks (Ramsey, 1999) and to allow the components of a non-stationary series to be analyzed. In comparison to the Fourier transform, the wavelet transform is an improved version of it.

In an influential study, Forbes and Rigobon (2002) note that heteroscedasticity biases contagion tests based on correlation coefficients. They show that it is not appropriate to look at unadjusted correlation coefficients, as the computed correlation coefficient is an increasing function of the variance of the underlying asset return, so that when coefficients between a tranquil period and a crisis period are compared, the coefficient in the crisis period is biased upwards, as volatility rises substantially. However, Corsetti et al. (2005) argue that this finding is a result of an assumed underlying unrealistic model and Bartram and Wang (2005) report that these biases come from assumptions about the stochastic process of stock returns. Furthermore, using multivariate GARCH models might also lead to bias estimation of correlations if trends are not accommodated for. Narayan and Liu (in press) show that a missing trend in a GARCH(1,1) model in the context of energy variables leads to model misspecification and the majority of the energy series including the oil price series show a positive trend (see Narayan et al., 2014). The solution to the problem could be to extend the trend-GARCH(1,1) unit root model proposed by Narayan and Liu (in press) to the multivariate framework. Although, as the authors argue, this could be computationally demanding.

Hence, when model-free correlation estimators are used, adjustments and trends are not needed. In this context, wavelets are a useful tool to compute correlations and the methodology is model-free.

So far, studies using wavelets to address changes on correlations due to shocks have focused on 2007–2008 crisis (see, e.g., Alaoui et al., 2015; Dajcman et al., 2012; Gallegati, 2012; Reboredo and Rivera-Castro, 2014). In this paper, we study the impact of sharp oil increases during the 1990–2011 period (for example the Kuwait and Iraq wars, the OPEC cutback in 1999 and the July 2008 oil peak) on four stock markets indexes: Germany, Japan, the U.K. and the U.S. An oil shock might change the correlation between country's stock market and oil prices. For instance, oil prices might increase, while the stock market value plummets or, on the other hand, oil prices might decrease, while stock market value remains unchanged or even soars, such as oil-exporting countries (Ramos and Veiga, 2013).

Our results show that in non-shock periods, correlation between oil and stock markets tends to be close to zero or slightly positive except in the period after 2008. At high frequencies, i.e., short periods of time, our results indicate changes in correlation between the U.S. stock market and oil in two periods; the Kuwait war and the July 2008 oil peak.

As we go from lower detail coefficients to higher detail coefficients, changes in the correlation between stock markets and oil are more frequent during oil shocks. For instance, the impact of the OPEC cutback period is only captured at low frequencies. We note also that during the July 2008 oil peak, at high frequencies the correlation between stock and oil markets drops, while at low frequencies it increases, indicating higher market integration.

Next, we test for changes in correlation between stock markets caused by an oil price shock, that is, we test whether correlation between international stock markets changes significantly during a period of oil market turbulence. Correlation between international stock markets might change because oil shocks might influence stock markets differently. For instance, the level of oil dependency can be different, as a country can be a net oil importer or a net oil exporter. Our results show that wavelet correlations between international stock markets are also different in shock and non-shock periods. Changes are visible at high frequencies but also at low frequencies, mainly between the U.S., the U.K. and German stock markets.

Finally, we analyze the impact of stock market shocks on the correlation of oil and stock markets. A financial shock might also change the correlation between oil and stock markets, as stock markets can plummet without impacting the price of oil. However, there is also the perception that with stronger links between markets, contagion can rise. Our results indicate that shock and non-shock periods tend to have statistically different correlations, that is, correlation changes during or after the crisis. The evidence on contagion is stronger for the period following the stock market instability of 2008 and 2011, while interdependence between international stock and oil markets shifts frequently during financial shocks.

[1] We refer the reader to the works of Basak and Pavlova (2014); Büyüksahin and Robe (2014); Domanski and Heath (2007); Hamilton and Wu (2015); Irwin and Sanders (2012); Ramos and Veiga (2014); Silvennoinen and Thorp (2013); Singleton (2013) and Tang and Xiong (2012).

[2] Wavelets are an alternative way of analyzing time series that are increasingly popular because they are based on elegant new mathematical results and efficient computational algorithms. By using wavelet methods in the context of multiresolution analysis, one can examine the series on a variety of scales. Different types of behavior, such as trends, cycles or extremes, may become evident at different levels of resolution. Unlike Fourier basis functions, which are only localized in frequency, wavelets are local both in frequency, via dilatations, and in time, via translations. Additionally, many classes of functions can be represented via fewer terms with wavelet transforms than with Fourier transforms. Functions with discontinuities and sharp spikes usually require fewer wavelet basis functions than Fourier basis functions. This sparse representation makes wavelets an excellent tool for data compression and statistical applications, such as the study of contagion and interdependence between financial markets. Finally, wavelet algorithms can also be implemented quickly, which is especially important with large amounts of data. For a review of the literature and discussion on the application of wavelets to economics and finance see Crowley (2007) and Ramsey (1999, 2002).