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Realized volatility transmission between crude oil and equity futures markets: A multivariate HAR approach

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ABSTRACT

This paper differs from extant literature because it studies volatility co-movements with a multivariate orthogonalized HAR model, a flexible specification for the time series of realized volatility, which is able to identify short-, mid- and long-term spillover effects. We examine volatility transmission mechanisms using high-frequency data of the stock index futures on S&P 500, Nikkei 225, FTSE 100 and the futures on the West Texas Intermediate crude oil during the period from September 2002 to September 2012. Considering the full sample, the short-term volatility of the equity futures contains information about future oil volatility incremental to the information inherent in the time series of oil volatility. On the other hand, weekly and monthly volatilities do not exhibit a significant spillover effect. Breaking the whole sample into three subsamples, no significant Granger causalities are observed in the pre-crisis period while in the crisis time and its aftermath, we document that the US and UK equity market volatilities to Granger cause the oil futures volatility which itself leads the Japanese market. In terms of magnitude, we observe an increase in the short-term volatility spillover over time. Studying the residuals of the HAR transmission models within a CCC/DCC-GARCH framework reveals increasing instantaneous correlation between the energy and equity volatilities in the course of time.

1. Introduction

Due to the rising amount of cross-asset acting investors and increasingly interlocking markets, financial market linkages are subject of rigorous research interest. Over the last decade, the number of contributions on cross asset price interrelationships has increased enormously and the question on how volatility is transmitted across major markets has triggered an outburst of studies based mostly on a multivariate GARCH framework.[1]

Oil is one of the key inputs for all major economies, which makes its relationship to various macroeconomic factors and stock market movements a topic of high practical importance. Many studies provide statistical proof of a significant link between oil price changes and returns on various equity markets. The literature on volatility interrelationships usually deducts either a spillover from oil price series to equity markets or a relationship of bidirectional nature (see Section 2). However, the various MGARCH specifications employed by most of the studies utilize returns sampled at a daily or lower frequency. Daily returns are known to provide noisy volatility estimates. In this study, we draw inferences about the volatility spillover mechanisms between the equity futures on S&P 500, Nikkei 225, FTSE 100 and the futures contracts on the light sweet crude oil West Texas Intermediate (WTI) using intraday data. These equity indices are chosen as established proxies of the US, UK and developed Asian equity markets. As these equity markets are highly liquid, numerous studies have already discussed the link between their returns and crude oil price movements. This fact allows us to compare our unique results for realized volatility series with the broad body of recent literature.

The contribution of this study is fourfold. First, it is the first to use a multivariate extension of the heterogeneous autoregressive (HAR) model of Corsi (2009) for realized volatility to explore the relationship between equity and oil market volatility. The HAR model is a powerful and flexible tool that is broadly acknowledged in the econometric literature mostly in its univariate version. The HAR model is a simple autoregressive-type model of realized volatility, considering volatilities realized over different interval sizes. It is very easy to use in practice and is shown to capture successfully the persistence of realized volatility for various forecasting horizons, and can be easily augmented by external variables. While the HAR model is an acknowledged volatility model in its univariate version, its application in multivariate settings is still rather scarce (see Section 2). Our analysis is based on the multivariate version of the HAR model as used by Bubák et al. (2011), who uncover volatility transmission between Central European currencies and the EUR/USD foreign exchange rate. The main advantage of the vector HAR (VHAR) model is its ability to split spillover effects in daily, weekly

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[1] For a review, see Soriano and Climent (2006).

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and monthly horizons, which cannot be done by means of the widely established multivariate GARCH framework.

Second, our methodological contribution is to extend the approach of Bubák et al. (2011) by using an orthogonalized version of the model. In particular, the equation of an asset's volatility contains the own volatility components as in the model's default univariate form whereas we employ an orthogonalized specification to capture the incremental information inherent in the realized volatility time series of a second asset. This approach aims to avoid ambiguous results caused by potential multicollinearity which may be emerging from a model setting within which realized volatilities of multiple assets are considered simultaneously. We focus on the volatility linkages of oil with the three equity markets in three separate bivariate models. To study the second moments of the volatility series, the residuals are considered within a CCC/DCC-GARCH(1,1) model by Bollerslev (1990) resp. Engle (2002). Hence, this study is unique in its investigation of the pattern of dynamic correlation between the second moments of equity and energy markets.

Third, the multivariate HAR model is fitted to the series of realized volatility of the assets under consideration. Realized volatility is a high-frequency data based volatility estimator and high-frequency data, which are known to improve volatility estimation substantially, are likely to allow for a far more precise analysis of the potential transmission patterns. In the case of S&P 500 and crude oil, the futures contracts are traded 24 h a day at the CME, so we do not need to cope with issues of overlapping trading and non-trading times between these assets. For Nikkei 225 and FTSE 100 index futures, the daily trading times are shorter in earlier years of the sample. However, since we are interested in lead–lag relationships of daily volatilities, the data allows for creating non-overlapping measures.

Last, our analysis covers the recent period from September 2002 to September 2012. Moreover, we discuss the volatility spillover effects between the equity futures and the crude oil futures markets for the full sample and due to the significant events influencing the markets over the last decade, we also split the volatility series into three subsamples. Results of the Granger causality tests, bivariate transmission models and correlation analysis are reported and discussed for the pre-crisis, crisis and after-crisis subperiods separately. This approach allows us to identify the source of the spillover effects found for the whole sample and to interpret their nature against the backdrop of major financial market events.

Focusing first on the whole sample period, we identify several causality relationships indicating that the equity markets are leading the volatility of crude oil. The interrelation between the realized volatilities in the full sample is mostly driven by the short-term shocks. The source of the volatility transmission appears to be the period starting with the financial crisis. Up until 2008, we find no evidence for significant Granger causalities. During the crisis, we can observe significant Granger causality going from the US and UK market to the oil futures volatility. The explanation is sought in the nature of the crisis which emerged from the markets for financial assets rather than from the overall shape of the economy. When the sub-prime market collapsed in 2008, the world economy followed these developments from the mid 2008. As broadly discussed in the literature (see Section 2), WTI can act as a gauge of the prevailing uncertainty of the overall macroeconomic environment and seems to lead the Japanese market in the short-term in our sample. The spillover effects persist in the period after 2009 with a strong relative impact of FTSE 100 on the oil market possibly due to the European sovereign debt crisis.

The analysis of the pattern of the conditional correlations shows additionally that there is a vast increase in the correlation during the recent capital market turmoil. The correlation observable after the global financial crisis is way higher than after the burst of the dot com bubble in 2001 and 2002. With appropriate caution, this might be interpreted as an additional evidence for the increasing integration of the equity and oil futures markets. Especially in the after-crisis period, we observe a decreasing strength of causality relationships on the one hand, and on the other hand, increasing instantaneous correlation indicating more pronounced simultaneous co-movements.

The rest of the paper is organized as follows: Section 2 reviews the literature on equity–oil market linkages and the HAR model. Sections 3 and 4 present the data and methodology. Section 5 discusses the empirical results and compares them with existing studies. Section 6 concludes the paper.

2. Literature review

Many scholars have discussed the relationships between oil prices and macroeconomic variables in detail. The pioneer papers of Hamilton (1983) and Gisser and Goodwin (1986) argue that oil price shocks might impact the future economic development and their findings are confirmed by many other studies, including Mork (1989), Lee et al. (1995) and Hooker (1996). As one of first, Jones and Kaul (1996) test the impact of oil prices on four developed markets using the cash-flow dividend model and find a significant negative correlation with the US stock market while the results for the Japanese and UK markets were inconclusive. However, more recent studies generally support the hypothesis that a significant link is present between numerous national stock indices and oil price time series (e.g. Basher and Sadorsky, 2006; Hammoudeh and Li, 2005; Park and Ratti, 2008; Sadorsky, 1999). Furthermore, some studies discuss the potential economic exploitability of such relationships (e.g. Arouri and Nquyen, 2010; Driesprong et al., 2008; Souček and Todorova, 2013).

Much attention has been paid to studying volatility transmission patterns, especially in equity markets (Soriano and Climent, 2006) whereas studies on oil markets are not so frequent. For instance, Malik and Hammoudeh (2007) show evidence for spillovers between oil prices, US, and the Gulf markets. Based on a multivariate GARCH analysis, Aloui et al. (2008) find oil volatility to have in general a negative impact on stock market development. Aloui and Jammazi (2009) use a Markov regime switching model to describe the course of volatility and show that oil price increases play a significant role in determining both the volatility of returns and the probability of transition across regimes. Chang et al. (2010), on the other hand, find only a little evidence for oil spillover in equity markets. Arouri et al. (2011) document a unidirectional spillover effect from oil to European stocks and a bidirectional relationship for US equities at sector level. Filis et al. (2011) support the results by, for instance, Choi and Hammoudeh (2010) and Chang et al. (2010) and show that the dynamic correlation between stock and oil markets exhibits time-varying patterns which are influenced by external information shocks. Malik and Ewing (2009) use bivariate GARCH models to simultaneously estimate the mean and conditional variance among five different US sector indexes and oil prices finding significant spillover effects. As previously mentioned, all contributions use return data sampled at a daily or lower frequency to examine volatility transmission mechanisms.

Since first discussed, numerous studies on financial market volatility have adopted the HAR model for realized volatility of Corsi (2009) (e.g. Ait-Sahalia and Mancini, 2008; Andersen et al., 2007; Bubák and Žikeš, 2009; Maheu and McCurdy, 2011) and a variety of model extensions has emerged. Giot and Laurent (2007) and Busch et al. (2011) examine the incremental content of implied volatility in the setting of a decomposition of realized volatility in jump and continuous elements. Corsi and Renó (2012) discuss the significance of leverage effects within the model and Corsi et al. (2012) address general nonlinear effects in volatility. In contrast, the literature using a multivariate HAR framework is rather scarce. Bauer and Vorkink (2011) propose a matrix-logarithm model of the realized covariance matrix of US stock returns. Bubák et al. (2011) use a vector HAR, to analyze volatility transmission between Central European currencies and the EUR/USD foreign exchange from 2003 to 2009. Against this backdrop, the current paper is clearly placed in the literature. It extends the empirical model