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The dependence structure across oil, wheat, and corn: A wavelet-based copula approach using implied volatility indexes

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ABSTRACT

This paper examines the dependence structure between three commodities implied volatility indexes (oil, wheat and corn) during bear, normal and bull markets and at different scales. For this purpose, we combine wavelet and copula methods to analyse the changes of the tail dependence at different scales or investment horizons. The results support evidence of time-varying asymmetric tail dependence between the pair of cereals as well as between oil and the two cereals at different time horizons – short-term horizon, medium term horizon and long term horizon, suggesting that the dependence structure is sensitive to time horizons. These results have important implications for the analysis of portfolio risk management.

1. Introduction

The interactions between energy and agricultural commodity markets have attracted the attention of economic actors in particular over the last 15 years which witnessed unprecedented booms and busts in energy and food prices (Mensi et al., 2014). Traditionally, agricultural prices have always been affected by energy (crude oil) prices through both input and output costs. The input costs include the costs of fertilizer and insecticides, which are heavily energy-intensive; whereas the output costs include the energy costs of the process of production, processing and transportation (see, among others, Tyner, 2010; Trujillo-Barrera et al., 2012). However, the recent expansion of biofuel cereal production, in light of the US government fuel policy, has further intensified the price linkages between energy and agricultural prices and raised concerns about a stronger volatility linkages and potential adverse impacts on economic actors. First, more volatile agricultural prices make price management risk more difficult and costly to agricultural producers (Wu et al., 2011), leading to less than optimal production and investment/hedging decisions. Second, increased price volatility of agricultural commodities makes poor consumers in countries dependent on cereals more vulnerable to price spikes and fears of scarcity, leading to grave hardship and potentially economic, social and political tensions. Increased price volatility also affects the design of optimal agricultural price stabilization and support policies. Third, stronger volatility linkages between crude oil and agricultural commodity markets weaken the diversification benefits of holding commodities in a portfolio.

Most of prior studies examine the intermarket volatility linakges using volatility proxies such as absolute returns, squared returns, or GARCH-based estimates. Such backward looking proxies are based on statistical inferences from past returns. Market traders are more concerned with future volatility measures such as implied volatility,

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which is found to be a better forecast of future realized volatility than historical volatility (Liu et al., 2013). Published by the Chicago Board Options Exchange (CBOE), implied volatility indexes measure the market's expectation of 30-day volatility and thus represent forward-looking gauges of market uncertainty. They are backed out from option prices, and accordingly, they do not only reflect historical volatility information, but also investors' expectation on future market conditions. To get benefits from the valuable informational content of implied volatility data and its superiority over other volatility measures, this study uses the newly published implied volatility indexes in studying the relationships across crude oil, wheat, and corn prices, an unexplored research area. By examining linkages among VIX in different markets, we can detect the relationship between price dynamics in the future.

In addition to the novelty of using CBOE implied volatility data in modelling the linkages between oil and agricultural commodities, this study offers another novelty through the employment of a combination of copula and wavelet techniques. Recently, wavelet methods and copulas have been very useful in modelling the relationships between financial variables, although they have often been used separately (see, e.g., Vacha et al., 2013; Filip et al., 2016; Kristoufek et al., 2016 for wavelet applications; Serra, 2011; Reboredo, 2012; and Koirala et al., 2015 for copula applications). However, irregular extreme values, time-varying volatility, abrupt jumps, nonlinear price dynamics, and skewed distributions are likely to affect the modelling of commodity prices. Therefore, the combination of wavelet and copulas allows us to capture these stylized facts of the commodity prices and explore the intensity and asymmetry of the dependence structure over different time scales. Lower time scales capture higher frequency time series components which occur over very short periods of time (short investment horizon), while higher time scales detect lower frequency components occurring over very long periods of time (long investment horizon). It is also worth noting that copula functions provide a great flexibility in separating the marginal distributions from the dependence structure and in modelling these distributions independently with the aim of providing information on average dependence as well as on the probability that two variables jointly experience extreme upward or downward movements.

Furthermore, the study sample period (July 27, 2012–May 20, 2016) allows us to draw a recent picture about the (implied) volatility linkages across crude oil, corn, and wheat markets, whereas most of prior studies have focused on the global financial crisis (GFC) of 2007–2008 and food crisis of 2006–2008. We thus cover a quite different, but interesting period for both energy and cereal agricultural markets during which crude oil prices have plunged noticeably since late 2014. As for wheat and corn markets, they experienced less turbulent price fluctuations, but underwent a steady decline. The biofuel industry has also decelerated aimed the sharp decline in energy prices.

Our main results show a dynamic asymmetric tail dependence between the pair of cereals and oil-ceral pair. The dependence structure varies at different scales and extreme dependence during bear and bull markets.

The remainder of the paper is as follows. Section 2 presents a literature review. Section 3 describes the empirical methods. Section 4 presents the data ad some preliminary statistics. Section 5 reports and discusses the empirical results. Section 6 concludes the paper.

2. Review of literature

There is a vast body of literature on the relationships between energy and agricultural commodity markets. Using cointegration, vector error corrections, and multivariate GARCH models, Zhang et al. (2009) examine return and volatility transmissions between US oil, ethanol, gasoline, corn and soybean prices and find no evidence of long-run relations among fuel (ethanol, oil and gasoline) prices and agricultural commodity (corn and soybean) prices. Using ARDL model, Chen et al. (2010) study the relationships among the prices of corn, soybeans and wheat, and the price of crude oil and show that the cereal returns are significantly affected by the returns of crude oil and other cereals. Using a stochastic volatility model, Du et al. (2011) show evidence of volatility spillover among crude oil, corn, and wheat markets after the fall of 2006. Using linear and non-linear causality tests, Nazlioglu (2011) shows a unidirectional non-linear causality running from the oil prices to the corn and soybean prices as well as evidence of nonlinear feedbacks. The results become all insignificant when the author applies the linear Granger-causal approach, suggesting the superiority of non-linear causality tests. Using a VECM-BEKK-GARCH model, Trujillo-Barrera et al. (2012) focus on the volatility linkages between the US energy and agricultural markets. Contrary to the findings of Zhang et al. (2009), they reveal strong link and significant volatility transmission from crude oil to corn and ethanol. Using cointegration and ARDL models, Sari et al. (2012) examine the prices of crude oil, gasoline, ethanol, corn, soybeans and sugar, while considering the impacts for the lagged grain trading volume and the open interest in the energy and cereal markets. They reveal a short-term two-way feedback in both directions in all markets. They also stress on the importance of trading volume, and not the open interest, for improving forecasts of futures prices in the long run. Inspired for the importance of non-linear modelling indicated by Nazlioglu (2011), and using both parametric and semi-parametric approaches, Abdelradi and Serra (2015) focus on the non-linearity in the European food-energy nexus and show that the prices of biodiesel, rapeseed oil and crude oil have a long-run equilibrium relationship. A quite similar study that focuses on the non-linear relationship between oil prices and agricultural commodity prices is conducted by Fowowe (2016) in South Africa. The author uses cointegration tests that allow structural breaks and non-linear Granger-causality test and provides evidence in support of the neutrality responsiveness of agricultural commodities in South Africa to international oil prices. Using cointegration and vector error-correction models, Jiang et al. (2015) examine the relationships among crude oil, corn, and plastic prices and conclude that crude oil price is a factor causing changes in both the plastic and corn future markets. Furthermore, they follow the lines from Du et al. (2011) and Wu et al. (2011) by applying a vector ARCH model and show the existence of volatility spillover from crude oil prices to corn prices. Koirala et al. (2015) use copula method and examine the dependence between agricultural commodity prices and energy prices. They report a high positive correlation between energy and agricultural commodity prices and show that an increase in the prices of crude oil, natural gas, gasoline, diesel, and biodiesel leads to an increase in the prices of corn and soybean.

The importance of biofuel production in intensifying the relationships between energy and commodity cereals has been the subject of several studies. Chen et al. (2010) highlight the role of biofuel production in the relationships among corn, soybeans, wheat, and crude oil prices. Tyner (2010) shows that along the biofuel boom in the period 2006–2008 the link intensified between crude oil, gasoline, and corn prices. Similar to Chen et al. (2010), Du et al. (2011) argue that expanding ethanol production in late 2006 has contributed to the increased market integration between crude oil, corn, and wheat markets. Han et al. (2015) use multivariate normal mixture models and show that the biofuel policy has slightly affected the price links between energy and agricultural commodities. In a more comprehensive analysis and using conditional and unconditional correlation coefficients, de Nicola et al. (2016) study the co-movements among the prices of 11 major energy, agricultural, and commodities over the period 1970–2013. They show an increase in the degree of co-movements between energy and agricultural prices in recent years and refer this to the expansion of the biofuel industry. However, Gardebroek and Hernandez (2013) question the common view that increased volatility in agricultural markets is due to the expansion of biofuel production. Filip et al. (2016) employ a combination of