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Time-frequency contained co-movement of crude oil and world food prices: A wavelet-based analysis

Debdatta Pal [a,*], Subrata K. Mitra [b]

[a] *Indian Institute of Management Lucknow, India*
[b] *Indian Institute of Management Raipur, India*

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ABSTRACT

This paper evaluates the association between crude oil prices and world food price indices, first within general space and time, and then within the combined time-frequency sphere. Monthly price data spanning from January 1990 to February 2016 were used for the analysis. The Johansen cointegration test conducted within the time domain confirmed the statistically significant cointegrated relationship between crude oil prices and the price indices of food and its sub-categories, such as dairy, cereals, vegetable oil, and sugar; however, frequency information was not accounted for. To incorporate both the time and frequency features of the data, we used a wavelet method that has shown that the world food prices, along with the prices of cereals, vegetable oils, and sugar, co-move with and are led by crude oil prices, results that remain relevant from the short-run policy perspective. The outcome of Toda–Yamamoto causality confirmed the spillover of crude oil price changes to the world food price index also in the long run. The paper ends with the policy implications of these results.

1. Introduction

Do crude oil and world food prices co-move? This question continues to be of great international concern, as several poor nations largely depend on both crude oil and food imports. During the food crisis from early 2006 until the middle of 2008, the price of major food crops, including wheat, soybeans, and corn, soared in concurrence with the rise in crude oil prices, which reached a historical high of $145 (U.S.) per barrel. The concurrent swings in crude oil and agricultural commodity prices were also observed in December 2008 when the crude oil price dropped to as low as $30 per barrel. Joint movement was further observed until crude oil prices steadily rose to around $124 per barrel by April 2011. Therefore, one of the ways to evaluate fuel-food price co-movement is to explore the causal price relationships between crude and agricultural commodities (Bazilian et al., 2011).

The predominant explanation (Hanson et al., 1993) of fuel-food co-movement is that an increase in crude oil prices makes the related agricultural resources such as fertilizer, chemicals, and transportation costlier, thus boosting the prices of these agricultural commodities. However, the current debate on fuel-food price co-movement has leaned more toward the idea that a upsurge in crude prices raises the demands of both soybean- and corn-based biofuels, that in turn increase the demands of both feedstocks, i.e., corn and soybeans, and thereby boosts their prices (Cha and Bae, 2011; Chen et al., 2010; De Nicola et al., 2016; Mitchell, 2008; Natanelov et al., 2013; Obadi and Korcek, 2014; Saghaian, 2010; Tyner, 2010). With the rapid expansion of the biofuel sector, farmers will likely be forced to produce food crops such as wheat or fuel crops (i.e., corn or its substitute the soybean). Such decisions would likely be guided by the profitability associated with the available alternatives (Zhang et al., 2010). Given that farmers would likely have to allocate more land for fuel crops, wheat could be in short supply, thus leading to a spiraling increase in its price.

Nevertheless, there are dissenting voices supporting the neutrality hypothesis that rejects the above fuel-food price nexus. For instance, Wiggins and Keats (2009) argue that the falls in corn prices in 2007–2008 resulted from the dismantling of public food stocks, and thus were not due to increased demands from the biofuel industry. Furthermore, Gilbert (2010) assigned price changes in agricultural feedstock to the influence of other common factors, namely, demands for growth, monetary expansion, and exchange rate movements, thus disassociating such changes from crude oil prices and increased biofuel demands. In their study, Nazlioglu and Soytas (2011) revealed that

* Corresponding author at: Indian Institute of Management Lucknow, Lucknow 226013, Uttar Pradesh, India.
E-mail address: debdatta@iiml.ac.in (D. Pal).

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agricultural commodity prices in Turkey reacted weakly to crude oil price fluctuations in the short run. By using the copula model on weekly data from the period of 1998 to 2011, Reboredo (2012) found only weak support for the fuel-food nexus. Along similar lines, Myers et al. (2014) have suggested that crude oil and feedstock prices co-move only in the short run; however, corn price is primarily influenced by improved productivity, higher available acreage, and increased demands for livestock feed. Lopez Cabera and Schulz (2016) also revealed that biodiesel production cannot adequately explain the price co-movement between crude oil and agricultural feedstocks. Similar weak linkage was also evidenced by Drabik et al. (2016).

However, despite these research contributions, there is a growing body of literature that attributes the crude oil and agricultural commodity co-movement to the rapid integration of stock and bond markets with commodity markets, specifically during the financial crisis, which is referred to as "financialization" (Olson et al., 2014). For example, Adams and Gluck (2015), Creti et al. (2013), Han et al. (2015), and Nagayev et al. (2016) have attributed the price link between crude oil and agricultural commodities to the global financial crisis due to the increasing use of agricultural commodities as financial assets during this time. From the early 2000s, investment in commodity markets, including energy and agricultural commodities, has been marked by a spectacular rise from $15 billion in 2003 to $250 billion in 2009 (Irwin and Sanders, 2011). The reasons behind this financialization of the agricultural commodity market are thought to be: (1) poor performance of the traditional investment instruments such as stocks and treasuries, leading to investors starting to explore new assets for higher returns (Brooks and Prokopczuk, 2013); (2) since the factors driving agricultural commodity prices (e.g., weather variations, supply constraints) are different from those influencing the values of equities and bonds (Geman, 2005; Geman and Kharoubi, 2008), commodity prices exhibit lower correlation with the traditional asset class; (3) commodities extend more effective inflation hedge over stocks and bonds (Bodie, 1983); and (4) while prices and volatility are positively correlated in the energy commodity market, they tend to be negatively correlated in the equity market (Doran and Ronn, 2008).

The majority of empirical investigations into the fuel-food price link have employed standard time-series approaches that include vector autoregressive (VAR) models as well as autoregressive distributed lag (ARDL) models. Asymmetric price links have been assessed using nonlinear versions of ARDL (Ibrahim, 2015; Rafiq and Bloch, 2016), cross-correlation (e.g., Liu, 2014), Granger causality (e.g., Nazlioglu, 2011), and vector error correction models (VECM) such as the asymmetric VECM, threshold VECM, smooth transition VECM, and Markov-switching VECM. In recent times, price volatility has been examined through the use of multivariate versions of autoregressive conditional heteroscedastic (ARCH) models. All these time-series methods primarily include information pertaining to time while ignoring important information from the frequency domain (Power and Turvey, 2010; Huang et al., 2016). However, the concealed information on frequency is one of the key causes leading to nonlinearity in time-series assessments (Manimaran et al., 2009; Huang et al., 2015). The relationships between crude oil and agricultural commodities in time-series analyses are generally expected to behave nonlinearly. The nonlinearity between fuel-food prices implies that the prices of corn and soybeans, two major feedstocks, as well as wheat, the major food grain, increase rapidly and in greater magnitudes in response to rises in crude oil prices; however, feedstock prices change more slowly and in a smaller magnitude when crude oil prices drop. For example, Nazlioglu (2011) found support for nonlinear price transmission from crude oil to agricultural commodities by employing a nonlinear Granger causality test. Similarly, Balcombe and Rapsomanikis (2008) confirmed asymmetric price transmission from crude oil to sugar in Brazil by using a nonlinear vector error correction model. Along the same lines, Serra et al. (2011) also found that corn prices respond asymmetrically to crude oil price changes in the U.S. More recently, Pal and Mitra (2016) found that soybean price movement in the U.S. is tail-dependent and differs over quantiles by employing the Quantile Autoregressive Distributed Lag (QADL) method to examine the link between diesel and soybean prices. Researchers (see for example, Abdelradi and Serra, 2015; Ahmadi et al., 2016) also explored price volatility approach for assessing the fuel-food nexus.

There have been plenty of investigations exploring co-movement among crude oil and agricultural commodities; unfortunately, the conclusions often conflict. This may be partly attributed to the omission of information regarding frequency in the existing time-series studies. Therefore, it is both timely and relevant to assess this previously-unused information in a combined time-frequency sphere, which will allow for more appropriate identification of the changes pertaining to various frequency components hidden within the time series. In addition, this approach is expected to facilitate finer insight into the complex processes involved in determining the relationship between fuel and food prices. Finally, the outcome of this analysis will hopefully shed more light on the increasing financialization of commodity markets, as the price and risk transmission from crude oil to food eventually carry over to other individual markets such as corn and soybean cultivation, which are also the primary feedstocks for biofuel.

We aimed to detect and quantify the time-frequency dependence of crude oil and global food prices. With this purpose in mind, we employed wavelet analysis (Goupillaud et al., 1984), a method from statistical physics that combines information about both time and frequency. In empirical inquiries, methods focusing on either time space or frequency space are, in general, applied independently. However, given that the real-world data are often non-stationary, such estimations may not be fully accurate. Furthermore, if any structural break is experienced within the time series, the results from a traditional time domain technique with fixed parameters may be flawed. In these particular circumstances, we required a method that allowed the localization of such breaks in empirical probing. On the other hand, the key problem with a standalone frequency domain approach, more specifically referred to as the Fourier transform, is that by focusing solely on the frequency domain, the information from the time domain is completely omitted. Here also the unit root of the time series is of high significance. The novelty of wavelet analysis is that it allows the decomposition of unidimensional time data into the bi-dimensional time-frequency sphere. This decomposition to frequency components or scales allows for separation to be established between long- and short-term behaviors.

In one of the earliest studies of this nature, Davidson et al. (1997) postulated a technique built upon the wavelet approach for studying the price behavior of agricultural commodities. Later on, Connor and Rossiter (2005) used wavelet analysis to assess co-movement between crude oil and agricultural commodity prices by decomposing time series into scales. However, they made use of a very discrete type of wavelet transformation. Vacha et al. (2013) was the first to employ a continuous type of wavelet transformation, followed by Dedeoglu (2014) and Kristoufek et al. (2016), to explore price co-movement among crude oil, ethanol, biofuel, wheat, and agricultural feedstocks. Vacha et al. (2013) revealed that in the stable period, ethanol and biodiesel were correlated with corn and German diesel, respectively, primarily within the low frequency (high scale) range. Working on the monthly time series spanning from January 1988 to April 2012, Dedeoglu (2014) concluded that fossil fuel and agricultural commodity figures were weakly correlated for the short, medium, and long run; however, increases were reported post-2008 for the medium run. By using the method of continuous wavelet analysis, Kristoufek et al. (2016) also found support for price co-movement between ethanol and corn (in the U.S.) as well as sugar (in Brazil), where prices of ethanol were found to be led by the feedstock prices. In line with the studies conducted by Vacha et al. (2013), Dedeoglu (2014), and Kristoufek et al. (2016), we also performed continuous type wavelet coherence analysis. However, our work here differs from that of the earlier studies in the following way: they assess co-movements among the prices of crude oil, wheat,