Theoretical and Applied Economics
Volume XXI (2014), No. 6(595), pp. 37-50

Evolution of comovement between commodity futures: does biofuels matter?

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Abstract. *In this study, the linkages of commodity futures are investigated for the period 1988:M1-2012:M4. Monthly futures prices for nine commodities are utilized throughout the empirical analyses. As the empirical approach, wavelet analysis is chosen to investigate the comovement of commodity futures. By using wavelet based measure of correlation, the correlation between commodity futures are determined both in time and frequency domain. The results indicate that correlations are low for short, medium and long-run. I also find evidence of a tendency towards an increase in correlations after 2008. This can be the result of the global crisis that has an effect on feedstock costs and energy input prices by putting front a channel through biofuels that links energy and agricultural commodities by increasing the correlation between these commodities after 2008.*

Keywords: wavelet analysis, comovement, energy futures, agricultural commodity futures, biofuels.

JEL Classification: G15, Q42, E44.
REL Classification: 15F.

1. Introduction

Energy is not only a primary cost item for firms but it also enters to household heating and transportation expenditures. Food prices can affect firm costs through wages. Food expenditures as a share of total expenditures, particularly in low-income households, are high. It is evident that both energy and agricultural commodity prices are among inflationary factors. As a result of this, policy authorities are required to consider both commodity price movements and comovements. The existence of comovement between the prices in agricultural and energy markets is one of the issues that should be considered in policy making. In a different vein, Runge and Senauer (2007) warn that “biofuels have tied oil and food prices together in ways that could profoundly upset the relationships between food producers, consumers, and nations in the years ahead, with potentially devastating implications for both global poverty and food security.” It is evident that the existence of price comovement in commodity markets has important implications for different parties including consumers, producers, investors and policy makers.

As a potential link between energy markets and agricultural commodities, biofuels are receiving increased attention. According to Peñaranda and Micola (2011) there is a plausible economic logic for an oil-food connection through biofuels. Many researchers point out the biofuel industry as a potential channel that affects the linkage (Banse et al., 2008; IHT, 2008; Rajagopal et al., 2007; Ren21, 2007; Campiche et al., 2007; Francisco and Augusto, 2009; Harri et al., 2009; Hertel and Beckman, 2010; Peri and Baldi, 2010; Tyner, 2009; Yu et al., 2006; Peñaranda and Micola, 2011). Even though authors present evidence in favor of the existence of such a link, the evidence is not that much clear-cut.

If we assume that there is such a linkage the three possible sources of correlation between oil and biofuels are interfuel substitution, costs and financialization (Peñaranda and Micola, 2011). Oil and biofuels are often considered substitutes. If interfuel substitution is prevalent, changes in oil prices will affect the demand for biofuels by leading changes in their prices. This in turn will affect the demand and the price of feedstock commodities. Agricultural production includes energy intensive activities such as the use of fertilizers, transportation and agricultural field machinery usage. According to NASS (2011), the total of all energy intensive activities account for a high share of the non-feedstock biofuel production cost. Accordingly, energy price alterations lead to agricultural commodity price changes. In futures markets oil is used as a reference commodity and takes a large part in the calculation of most commodity indexes. Therefore, comovement would influence all index components, regardless they are used in the manufacturing of biofuels or not. The above three channels between oil and biofuel commodity prices can lead to comovement between energy and agriculture commodity prices.

This study examines the co-movement between the futures prices of oil and several commodities by using a wavelet analysis which enables assessing the contemporaneous co-movement between the futures prices of oil and commodities both in the time and frequency domains.

The remainder of this study is as follows: Section 2 reviews the literature. Section 3 describes the data and methodology, Section 4 provides the empirical findings and Section 5 concludes.

2. Literature review

The literature on commodity prices can be separated into three strands. The first strand examines the excess comovement, the second examines the effects of changes in energy prices on world markets and the third examines the effects of crude oil and other energy prices on other commodities.

The idea of excess comovement between commodity prices is introduced by Pindyck and Rotemberg (1990). According to them, the correlation of the prices of the commodities with different fundamentals which cannot be explained by macroeconomic effects is called excess comovement. They argue that, due to herd behavior, prices tend to move together. By herd behavior they mean the bullish or bearish manner of traders on all commodities for no plausible reason. Deb et al. (1996) suggest the use of a GARCH framework due to the prevalence of nonnormality and heteroskedasticity of the commodity price changes. These models find weak evidence of comovement using the same commodities and the same time interval as in Pindyck and Rotemberg (1990). Ai et al. (2006) re-examined comovement between agricultural commodities. By using a structural model they are able to explain a substantial part of the correlation between commodities. However, the structural model in Ai et al. (2006) falls short in explaining the comovement between the prices of the commodities with different fundamentals.

Another strand of the literature examines the direct and indirect effects of changes in energy prices through macroeconomic impacts on world markets. (Gohin and Chantret, 2010; Uri, 1996; Lardic and Mignon, 2008; He et al., 2010). Crude oil markets even seem to affect the stock markets (Ciner, 2001; Ghouri, 2006; Miller and Ratti, 2009; Papapetrou, 2001). Various other studies suggest that crude oil prices have statistically significant effects on economic activity (Adrangi et al., 2001; Berument et al., 2010; Brown and Yucel, 2001; Costantini and Martini, 2010; Fofana et al., 2009; Hamilton, 2009a; Hamilton, 2009b; Hanabusa, 2009; Hsing, 2007; Huang et al., 1996; Jayaraman and Choong, 2009; Jiao and Ma, 2006; Jones et al., 2004; Odusami, 2010; Oladosu, 2009; Papapetrou, 2001; Rafiq et al., 2009; Reynolds and Kolodziej, 2007; Zagaglia, 2010).

Furthermore, a third strand in the literature includes studies examining the effects of crude oil and other energy prices on commodity futures. Gohin and Chantret (2010) found a significant relationship between world energy and food prices by employing a general equilibrium model. Baffes (2007) suggests that if crude oil prices remain high for a certain time period then the most recent commodity price boom is likely to last much longer than earlier booms, at least for food commodities. However, other commodities are likely to follow diverging paths. Plourde and Watkins (1998) document that that short-term price volatility of various commodities is lower than that of oil.

Reviewing the literature enables reconciling the existence of a possible impact of the crude oil futures prices and the agricultural commodity futures prices bilaterally. This study aims to uncover the direct linkages between crude oil and agricultural commodity futures prices rather than the prices of these commodities. Natalenov et al. (2011) argue that if herd behavior in financial markets can be observed, futures markets should reflect this behavior because this behavior is inherent in speculative instruments.

3. Data and methodology

Monthly cocoa, coffee, corn, crude oil, rice, soybean oil, soybean, sugar, and wheat futures prices are used in the analyses. The sample period covers 1988:M1-2012:M4. All data is obtained from Bloomberg Database.

This study investigates the linkages among monthly commodity futures prices. This, to some degree, enables extracting some information about the herding behavior of the futures prices. The analysis is conducted within a wavelet framework. The use of wavelet analysis is rare in economics, but its use in a wide variety of disciplines has been growing rapidly during the last two decades[(1)] (Crowley, 2007).

Rua (2010) states that time domain approaches[(2)] reveal the evolution of the comovement between variables by capturing the time varying features, whereas frequency domain approaches[(3)] reveal the evolution of comovement across frequencies. Wavelet analysis reconciles both the time domain approach and the frequency domain approach. Eventually this enables assessing the relationship between variables at different frequencies and the evolution of the relationship through time.

The Fourier Transform is the conventional method for studying a signal (time series) in frequency domain. It enables translating a time series into the sum of well-chosen sinusoidal basis functions. Using this method the signal in time domain is transformed into frequency domain. However, this transformation removes the time domain features of the signal which can convey essential information while analyzing a nonstationary time series. For such a signal the time interval in which the spectral components (e.g. transient jumps etc.) occur can be important (Yazgan and Korürek, 1996). In other words, the Fourier transform provides information about how much of each frequency component is in a signal (time series) but it provides no information about when this frequency exists (Rua, 2011). The Short-Term Fourier transform (also known as Gabor or windowed Fourier transform) is introduced as a remedy for this limitation. In this transformation the signal is cut into slices by using a window function (also known as window) with a definite length.(4) After this, the Fourier transformation is applied to each segment. According to Heisenberg's Uncertainty Principle, the frequency at a specific time cannot be exactly known so it is only possible to obtain what spectral components exist at a given time interval (Rua, 2011). This means that some frequency resolution should be sacrificed for a better time resolution. In other words, the frequency resolution and time resolution are related with window width positively and negatively respectively (narrow window width good time resolution, poor frequency resolution and vice a versa). An important limitation of the short-term Fourier Transform is the inflexibility of the window length for different frequency components. The wavelet transform becomes a remedy to solve this problem. The wavelet transform enables us to widen or narrow the window width according to frequency i.e. narrow window for high frequency, wide window for low frequency.

Wavelet, by definition, stands for small waves which begin and die out at different finite points in time. In other words, wavelets are finite length oscillatory small waves and they are best described with elementary functions. The wavelet transform enables decomposition of time series in terms of the elementary functions or namely wavelets(5). Wavelets can either be stretched or squeezed in order to mimic the original series which enables to generate locally approximating variables in time or space. In other words, any series can be built up as a sum of projections onto wavelets with different scales and time positions (Crowley, 2007).

Wavelets can be distinguished into two main categories, such as father and mother wavelet, according to integration. The father wavelet integrates to one where the mother wavelet integrates to zero. The father wavelet (scaling function) and mother wavelet represent the smooth trend (low-frequency) part and the detailed (high frequency) part respectively (Crowley, 2007). All wavelets can be generated from mother wavelets. A mother wavelet is a wavelet that should satisfy a number of both regularity and admissibility conditions (see Mallat, 1998).

A wavelet with scale, s and time, u is defined as

$$\psi_{s,u}(t) = \frac{1}{\sqrt{s}}\psi_{s,u}\left(\frac{t-u}{s}\right) \qquad (1)$$

$\psi_{s,u}(t)$ is a wavelet with scale, s and time, u. $\frac{1}{\sqrt{s}}$ is the normalization factor[6], ψ is a mother wavelet.

There are various shapes of wavelet such as Morlet, Mexican hat, symmlet and daublets. In practice, the most commonly used wavelet is the Morlet wavelet (a kind of mother wavelet). A Morlet wavelet can be defined as

$$\psi(u) = \pi^{-1/4} e^{i w_0 u} - e^{u^2/2} \qquad (2)$$

A Morlet wavelet is a complex sine wave within a Gaussian envelope. The number of oscillations of the wavelet within the Gaussian envelope is determined by the parameter ω_o that represents the central frequency (Bigot et al., 2011). Put differently, it represents the wave number and the number of oscillations that are determined by this parameter.[7]

Let x_t denote a random time series, then a wavelet transform of x_t at scale $s > 0$ (dilation parameter) and time u (translation parameter) is defined as (Mallat, 1998).

$$W_x(s,u) = \sum x_t \overline{\psi}_{s,u}(t) \qquad (3)$$

where $\overline{\psi}_{s,u}(t)$ is the complex conjugate of $\psi_{s,u}(t)$.

The continuous wavelet transform with respect to $\psi(t)$ can be explicitly written as

$$W_x(s,u) = \int_{-\infty}^{+\infty} x(t)\overline{\psi}_{s,u}(t)dt = \frac{1}{\sqrt{s}}\int_{-\infty}^{+\infty} x(t)\overline{\psi}\left(\frac{t-u}{s}\right)dt \qquad (4)$$

Also, the time series x_t can be obtained through the inverse wavelet transform which is defined as follows

$$x(t) = \frac{1}{C_\psi} \int_{-\infty}^{+\infty} \left[\int_{-\infty}^{+\infty} \frac{1}{\sqrt{s}} \psi\left(\frac{t-u}{s}\right) W_x(s,u) ds \right] \frac{du}{u^2} \tag{5}$$

By using the wavelet transform the wavelet power spectrum of time series x_t, which is defined as $|W_x(s,u)|^2$, can be obtained. The wavelet power spectrum can be used to measure the relative contribution to the variance of x_t at each scale and time. Obviously, the integration of the wavelet power spectrum both across scale and time gives the total variance of the series. If the aim is the comparison of two time series, the wavelet power spectrum can be extended to do this. For two random times series, namely x_t and y_t, the extended wavelet power spectrum, which is called wavelet cross spectrum (WCS), is defined as $WCS_{xy} = W_x(s,u)\bar{W}_y(s,u)$ where $\bar{W}$ stands for complex conjugate. This measure enables obtaining covariance between the series x_t and y_t. In other words, WCS shows the areas where two time series have a high common power (Vacha and Barunik, 2012). WCS in wavelet analysis is analogous to covariance in time series analysis but provides no information about the strength of the relationship because it is not bounded to specific values (not normalized). A remedy for this shortcoming is normalizing the WCS and obtaining wavelet coherency (also known as wavelet squared coherence or WCO) which is similar to normalizing covariance and obtaining correlation coefficient in time series analysis. Putting differently, WCO is a normalized measure of the linear relationship between two time series by the individual power spectra. WCO enables measuring the coherence of two time series as a function of time and scale (frequency). Analogous to Fourier coherence, WCO is defined as

$$WCO_{xy}^2 = \frac{|WCS_{xy}(s,u)|}{\sqrt{|W_x(s,u)|^2 |W_y(s,u)|^2}} \tag{6}$$

WCO_{xy}^2 takes values between 0 and 1 depending on the strength of the relationship. In the absence of a relationship between series, WCO_{xy}^2 takes the value of zero. If there is an exact linear relationship both measures take the value of 1. Hence, a wavelet coherency value which is close to 1 can be interpreted as evidence for significant time-frequency correlation between series.

It is evident that since WCS is a complex function, WCO_{xy}^2 has an imaginary part, besides it disregards the phase differences. Considering this fact, Rua (2010) proposed a new measure analogous to the dynamic correlation of Crox et al. (2001). The dynamic correlation is a measure related to squared coherency; similarly, the new measure of Rua (2010) is related to wavelet squared coherency. Rua (2010) proposes the real part of WCS which is normalized by individual spectras of the two time series as the new measure and defined as

$$\rho_{xy} = \frac{\Re(WCS_{xy}(u,s))}{\sqrt{|W_x(u,s)|^2 |W_y(u,s)|^2}} \qquad (7)$$

where $\Re$ denotes the real part of WCS. According to Rua (2010), ρ_{xy} can be seen as a generalization of the dynamic correlation measure of Croux et al. (2001), and it allows assessing the strength of the contemporaneous comovement over both time and frequency. The value of the wavelet based measure, ρ_{xy} , ranges between -1 and 1 in a similar way to the standard correlation coefficient and the dynamic correlation proposed by Croux et al. (2001).

4. Empirical results

The results on comovement of all commodity pairs are illustrated in contour plots. For convenience, comovement results for both futures prices and returns are provided. For each contour plot, the vertical axis and horizontal axis show the frequency in terms of years and time respectively. Gray scale represents the topographic features of the surface. The gray scale darkens along with the increase in the height of the surface. In other words, the increase in wavelet based measure corresponds to darkening in the scale. There are ten commodity futures price pairs that consist of cocoa, coffee, corn, crude oil, rice, soybean oil, soybean, sugar and wheat. The pairs are given at the top of each contour plot.

The first set of contour plots in Figure 1 represents the comovement of commodity futures prices. The examination of comovement between oil and agricultural commodity futures prices reveals that, in general, the pairs seem to have low correlation for the whole sample period. However, in the medium-run after around 2008, the correlation between provided pairs tends to increase. The second set of contour plots in Figure 2 illustrates the comovement of commodity futures returns. The evidence on returns is consistent with the one obtained using commodity futures prices.

Figure 1. *Comovement of Commodity Futures Prices*

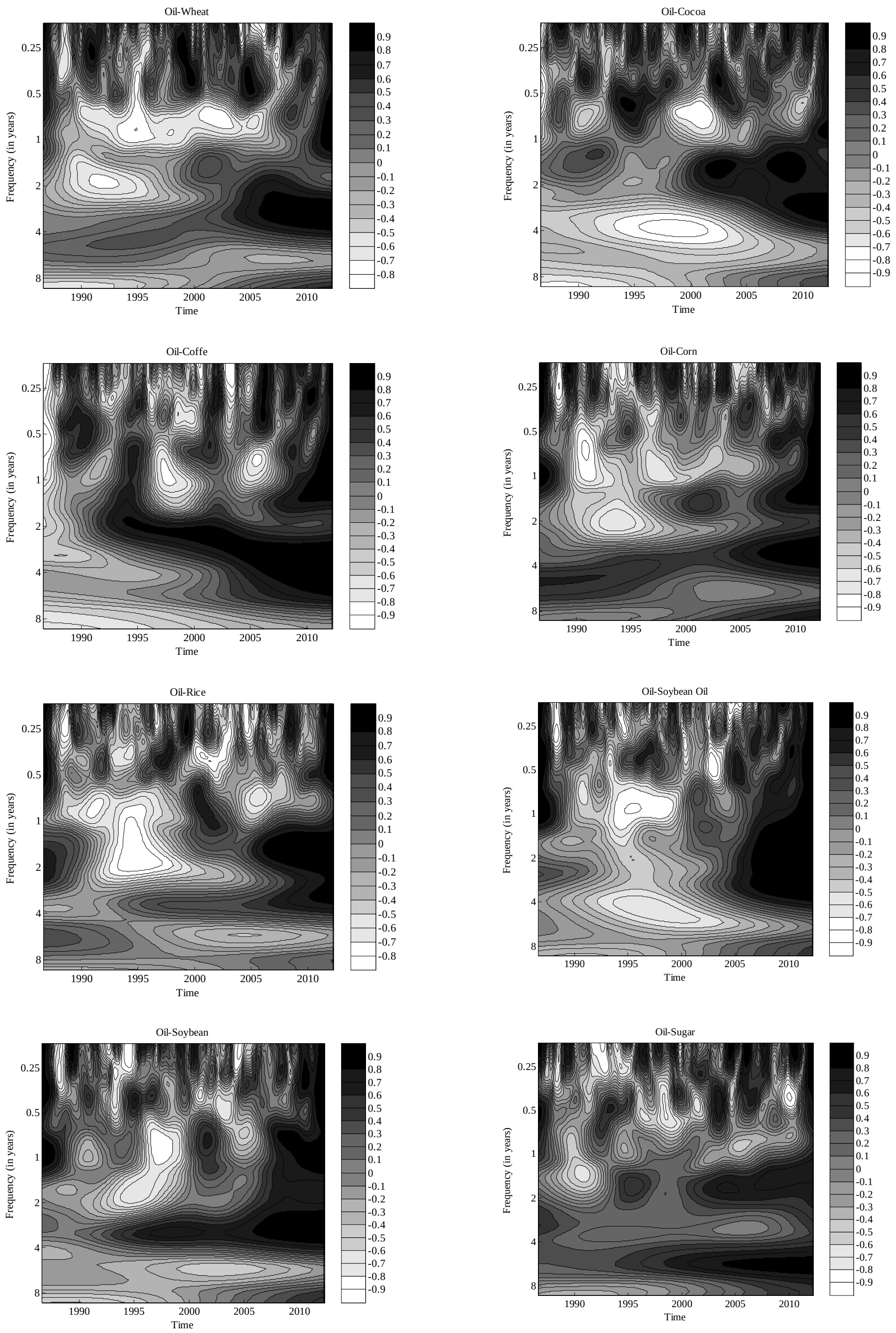
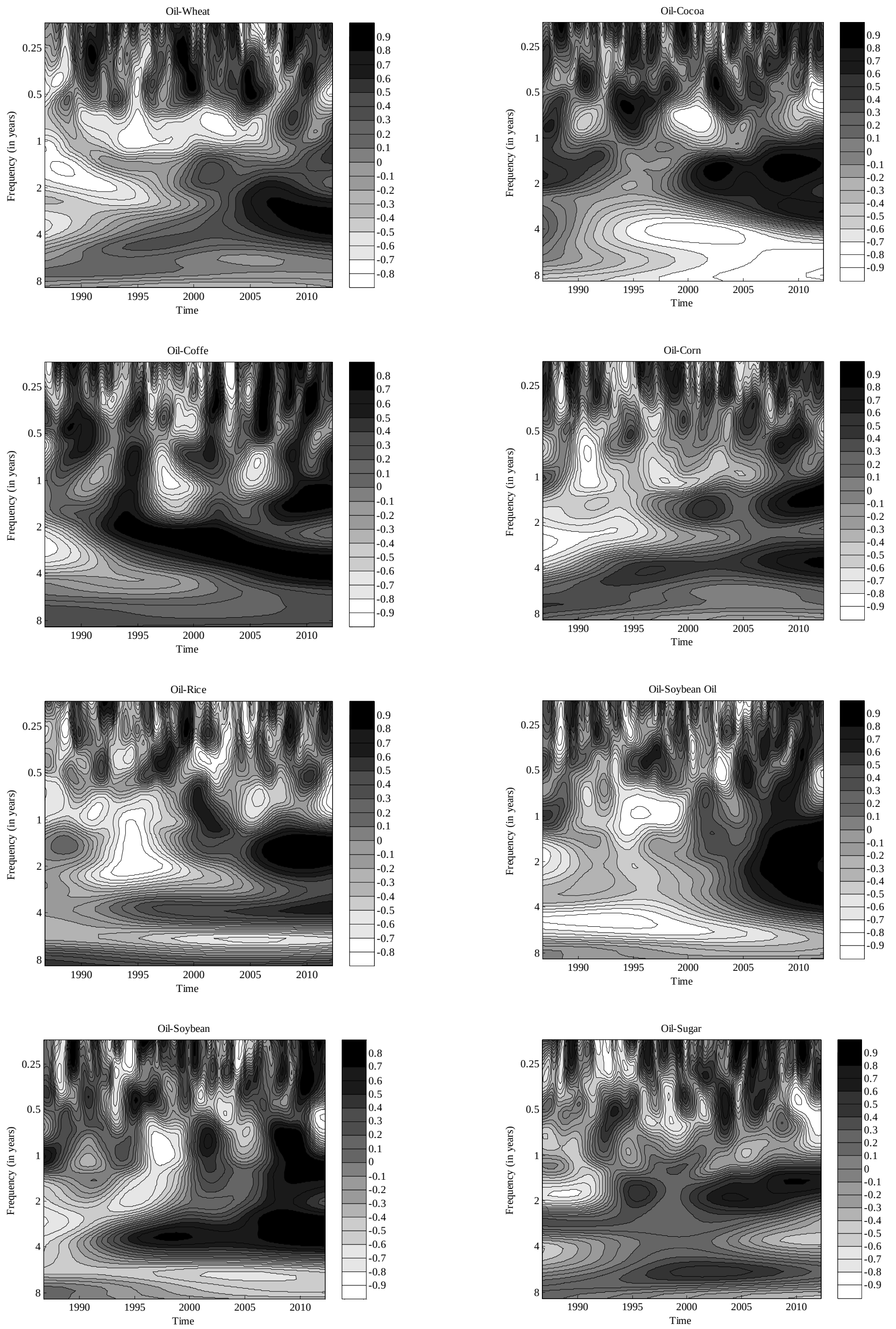


Figure 2. *Comovement of Commodity Futures Returns*



5. Conclusions

This study investigates oil and agricultural commodity linkages. Monthly commodity futures prices are used cocoa, coffee, corn, crude oil, rice, soybean oil, soybean, sugar, and wheat. Wavelet analysis is employed to investigate the co-movement behavior of commodity futures prices. The wavelet base measure of correlation enables us to study the correlation between commodity futures in both time and frequency domains. The results document that the correlation level is low in the short, medium and long-run. However, it tends to increase after 2008 for the medium-run, particularly for oil-soybean, oil-soybean oil and oil-sugar pairs.

The main production inputs for biofuels are Brazilian sugarcane ethanol, US corn ethanol and soybean oil biodiesel (OECD, 2006). Soybean and corn are feedstock for ethanol production where soybean oil is an input for biodiesel production. Since the biofuel production techniques are standard, feedstock costs, the price of energy inputs, the output prices and the potential to sell byproducts show up as the drivers of biofuels (Peñaranda and Micola, 2011). The 2008 sub-prime mortgage crisis could have affected feedstock costs and the price of energy inputs. This may have revealed a channel through biofuels which links energy and agricultural commodities by increasing the correlation between them after 2008.

Notes

(1) Cowley (2007) provides a guide and survey for economists.

(2) e.g. Rolling window correlation coefficient.

(3) e.g. Dynamic correlation.

(4) A window function is a function zero-valued outside of some chosen interval. The product of another function or waveform/data-sequence with a window function is also zero-valued outside the interval.

(5) Wavelets correspond to the sines and cosines in the Fourier Transform (Rua, 2011).

(6) The wavelet function at each scale s is normalized to have unit energy in order to ensure that the wavelet transforms at each scale are directly comparable to each other and to the transforms of other time series. (see Torrence and Campo, 1998). In other words the normalization by $1/\sqrt{s}$ equalizes the variance of the scaled mother wavelet and the original one (Rua, 2011).

(7) In practice this parameter is set to 6 (Torrence and Campo, 1998) and (Rua, 2010).

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