Multivariate GARCH to Measure Volatility Transmission Between Oil and Food Markets

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Abstract:

The movements in the global food prices have been of large interest to the different states because of the challenging effects on their macroeconomic indicators. The causes beyond the large swings in the global food market are several in which we find globalization and market interrelationship as one of the most important causes of the recent uprising volatility in this market.

This paper highlights the latter issue and analyzes the role of the volatility existing in the international oil market in driving the global food prices fluctuations. To do so, a bivariate GARCH model is used to show the volatility spillover between oil and food markets. A diagonal BEKK specification shows evidence of a link between volatilities in the returns of oil prices and weighted index of a set of important food commodities prices.

Key words: food prices, oil prices, volatility transmission, MGARCH.

(JEL) Classification:L66,F21, P28

ملخص:

اكتست التقلبات في أسعار الغذاء العالمية اهمية كبيرة في دول مختلفة بسبب الآثار الصعبة على مؤشرات الاقتصاد الكلي. الأسباب وراء التقلبات الكبيرة في سوق الغذاء العالمية هي عدة بحيث نجد فيها العولمة و ترابط الاسواق باعتباره واحدا من أهم أسباب التقلبات الأخيرة في هذا السوق.

وتبرز هذه الورقة مشكلة التقلبات تلك وتحلل دورالتطايرية الموجودة في سوق النفط الدولية في دفع الأسعار العالمية للغذاء للقيام بذلك، يتم استخدام نموذج الانحدار الذاتي المشروط بعدم ثبات التباين المعمم GARCH ذات المتغيرين لإظهار امتداد تقلب بين أسواق النفط و تقلبات اسعار الغذاء. وتظهر مواصفاتBEKK قطري دليل على وجود صلة بين التقلبات في عوائد أسعار النفط ومؤشر مجموعة من أسعار السلع الغذائية الهامة.

الكلمات المفتاحية: اسعار البترول، أسعار الغذاء، انتقال التطايرية، نموذج الانحدار الذاتي المشروط بعدم ثبات التباين المتعدد المتغيرات.

رموز **jel**: L66,F21,P28

Introduction

The most apparent result from the recent rise in food prices is that rising energy prices drive the food prices up. Indeed The worldwide surge in food crop prices has occurred at about the same time as the same surge in the price of crude oil, leading to a conclusion that oil and food crop prices have become more closely linked in recent years (see, e.g., Tyner 2010). This belief is argumented by the fact that energy is an important input in agricultural activities. Mallory, Irwin and Hayes (2012) provide evidence that this link was strengthened by the increased reliance on biofuels in industrialized economies, notably in the United States.

Many oil and food experts agree that oil prices affect food prices in different ways (see, e.g.,Westhoff 2012). Many examples could be given to show the link between oil prices and food prices. For instance, corn is used both as food and as a raw material in producing ethanol which is used itself in oil in producing refined products such as gasoline and diesel, which means that one would expect higher oil prices to be reflected in higher corn prices.

Moreover, corn is also used to feed farm animals. Consequently increases in the cost of producing meat and dairy products puts upward pressure on meat and dairy prices. Anyhow,the prices of all agricultural products will be affected to the extent that diesel is used to power mechanized farm equipment. Thus, all kinds of food prices are directly linked to the price of crude oil.

The objective of this paper is to examine to what extent is the link between oil prices and food prices. We are not the first to raise this question. But the main addition however, is that we are more concerned by the relationship between the volatility of these prices rather the strict relationship between prices.

The remaining of the paper evolves as follows. Next section discusses some stylized facts. Third section will deal with a literature review on the volatility of food and oil prices. The econometric issue and methodology are given in section four. Section five gives the empirical results and main discussion followed by the main conclusion.

1- Literature review on the relationship between oil and food prices volatility:

Existing literature on the effect of crude oil on agricultural commodities is new; almost all studies related to this topic began after the 2008 food crises. Even so, several books, magazines, and articles have highlighted the many underlying issues related to the topic such as the main reasons for unprecedented food prices, and the reasons for high energy prices. Some studies have examined the relationship and the long-run relationship among soft commodities prices and in some cases among selected soft commodities prices and crude oil price.

Campiche*et al.* (2007) analyzed the co-variability between crude oil prices and soybean, soybean oil, corn, sorghum, palm oil, and sugar prices from 2003 to 2007 using a vector error correction model. The focus of the study was to investigate the co-integration between the mentioned food products and crude oil. Their co-integration results indicate that soybean and corn prices were co-integrated with crude oil price during the 2006-2007 time frame but not during the 2003-2005 period. Other results from the same study indicate that crude oil prices do not adjust to changes in the corn and soybean market. The authors concluded from their analysis that soybean prices seemed to be more correlated to crude oil prices than corn prices. These results confirmed Arshad and Hameed's (2009) results. One limitation to this study was the limited number of commodities the authors used to examine the co-integration.

Ghaith and Awad,(2011)attempted to investigate the possible long-term relationship between the prices of crude oil and food commodities represented by maize, wheat, sorghum, soybean, barley, linseed oil, soybean oil, and palm oil. Time series econometric techniques (Unit root tests, Co-integration, and Granger causality) were applied. The study utilizes monthly data over the period of 1980 to 2009. The results of this study reveal that there is a strong evidence of long-term relationship between crude oil and the food commodities prices. A traditional Granger Causality is used to check whether causality exists between two product prices. The outcome suggests that there is unidirectional causality between the prices crude oil and some of the food commodities under examination.

Arshad and Hameed (2009) addressed one specific question: is there a long-term relationship between petroleum or crude oil and cereal prices? They conducted unit root, co-integration, and Granger causality tests between petroleum and each of maize, rice, and wheat. It is hypothesized that the changes in petroleum prices play an important role in changing major cereal prices. The results in this study supported the hypothesis that there is evidence of a long-run equilibrium relationship between the two prices of the two products. These results suggest that the petroleum price factor is growing in significance in the cereal complex since modern agriculture depends heavily on the use of fossil fuel in every stage of food production and marketing. All of these results combined confirm the hypothesis that there is a relationship between crude oil prices and that of major cereals, and changes in petroleum prices play an important role in this game.

Yu *et al.* (2006) analyzed the co-integration and causality of higher crude oil prices on the price and demand for vegetable oils. They concluded that the influence of shocks in crude oil prices on the variation in vegetable oil prices is relatively small, which appears to reflect the results in Campiche (2007).

Fabiosa (2009) studied the impact of the crude oil prices on the livestock sector under a regime of integrated energy and grain markets. The author found that the correlation structure between crude oil and grain prices increased dramatically, becoming more statistically significant. According to the author, prior to the ethanol boom, the correlation between the crude oil prices and corn was -0.117 and this figure increased to 0.876 during the ethanol boom period, and as well for other grains.

Hameed (2009), using a longer sample, find evidence of a long term relationship between oil, corn, wheat and rice, with causality flowing from the fuel to the crops. They relate this effect to cost factors, namely, the growing reliance by modern agriculture on seed fertilizer technology that is highly dependent on chemical inputs derived from oil. They also argue that biofuel production is another dimension of the problem. But they focus on the indirect effect of acreage competition between wheat and corn. As explained below, that is probably not a major factor for wheat (as it is for soybeans) since wheat and corn have limited land overlap.

Trujillo-Barrera et al. (2011) studied volatility spillovers in the US from energy to agricultural markets in the period 2006-2011. They found significant spillovers from oil to corn and ethanol markets, which seem to be particulary strong in high volatility periods for oil markets. They also identified significant volatility spillovers from corn to ethanol markets.

Pala, (2013) investigated form of the linkage between crude oil price index and foodprice index, using Johansen Cointegration test, and Granger Causality by VECM. Empirical results for monthly data from 1990:01 to 2011:08 indicated that evidence for breaks after 2008:08 and 2008:11.This study found a clear long-run relationship between these series for the full and sub sample. Cointegrationregression coefficient is negative at the 1990:01-2008:08 time period, but adversely positive at the 2008:11-2011:08 time period. These results represent that relation between crude oil and food price chanced.

Abbot *et al.* (2008) looked into the relationship between rising crude oil prices and an increase in the United States current account deficit. According to the authors the steady increase in oil prices and the decrease in the value of the United States dollar resulted in higher corn prices in the United States as the decreased dollar resulted in cheaper corn exports in places like China and India.

However, Baumeister and Kilian (2013) in a paper examining the causation between the oil prices and the higher food prices; showed no evidence that corn ethanol mandates have created a tight link between oil and agricultural markets, oil price shocks have not caused morethan a negligible increase in retail food prices in recent years. The authors did not find any evidence that oil-market specific events or for that matter U.S. biofuel policies help explain theevolution of the real price of rice.

In other context, the volatility transmission from the oil market to the food market has been differently argued by the literature. In fact, Gardebroek and Hernandez (2012) followed a multivariate-GARCH model to evaluatethe level of interdependence and the dynamics of volatility across oil, ethanol and corn markets. Theirresults indicate a higher interaction between ethanol and corn markets in recent years, particularly after 2006. The authors did not find major cross-volatility effects from oil to corn markets. The results did not provide evidence of volatility in energy markets stimulating price volatility in grain markets.

Kaltalioglu and Soytas (2011) investigated the volatility spillover between oil, food consumption item, and agricultural raw material price indexes for the period January 1980 to April 2008. Using the Cheung-Ng procedure, they showed that variation in oil prices does not Granger cause the variance in food and agricultural raw material prices.However, there is bi-directional spillover between agricultural raw material and food markets.

3- *Data and methodology:*

Volatility has been extensively analyzed in the field of finance, and the tools developed in this research have in turn been applied to commodity prices. The goal of this paper is to show the association between price volatility in crude oil and global food commodities. A multivariate GARCH model is used while we choose the diagonal BEKK model as the most popular to detect the volatility transmission among these two markets.

Overview onARCH and GARCH models to measure volatility:

Homoscedasticity, one of the least squares (OLS) assumptions which means that the expected value of all error terms when squared is the same at any given point. In some cross sectional and financial time series, this assumption is violated and the problem of heteroscedasticity is present.

Instead of concerning this phenomenon as a problem to be corrected, Robert Engle (1982) suggested a model in which this problem is a variance to be modelled.

The model suggested by Engle is: ARCH (Autoregressive conditional heteroscedasticity) model ,is used to model and forecast variance of the error terms.

An ARCH model is defined as follow (Engle 1982) :

$Yt/\Psi t\text{-}1 \sim N(xt\beta, ht)$

$ht=h(\varepsilon t\text{-}1 , \varepsilon t\text{-}2 ,\ldots\ldots.,\varepsilon t\text{-}p , \alpha)$

$\varepsilon t = Yt - xt\beta$

Where :

Ψt-1 : a set of information available at (t-1)

β : a vector of unknown parameters

ht :the conditional variance of the error term

εt : error term

α : an unknown parameters

P : the order of the ARCH process.

In order to simplify, the model can be defined :

$\sigma^2 = \alpha o+\Sigma\alpha i\varepsilon^2 t\text{-}i \quad : i=1,,,,,,p$

Where : ht = σ^2.

In 1986, Bollerslev developed a generalized ARCH (GARCH) model which can be defined in the equation below:

$\sigma^2 = \alpha o+\Sigma\alpha i\varepsilon^2 t\text{-}i + \Sigma\beta j\ \sigma^2 t\text{-}j \quad : i=1,,,,,,p \quad j=1,,,,,,q$

This equation means that the conditional variance depends not only on the squared lagged error terms but also on the variance itself.

ARCH and GARCH models are right if :

$\forall i, j : \alpha o > 0 , \beta j \geq 0 , \alpha i \geq 0$

Multivariate GARCH and volatility transmission:

According to the univariate ARCH and GARCH models demonstrated above, the current value of a variable depends only on its past value regarding the set of past information. However, the financial reality shows that a price and return movement in one market can spread very quickly to other market, i.e. financial markets are interrelated. Consequently, a set of multivariate GARCH type models have been specified to test for the covariances between the asset returns over time: the VECH model (Bollerslev, Engle and Wooldridge (1988)); the BEKK model (Baba, Engle, Kraft and Kroner (1990)) and the CCC (Bollerslev (1990)) and DCC (Engle (2002)); constant and dynamic conditional correlations, respectively.

In our case, we use the diagonal BEKK model to test for the volatility transmission between oil and food markets. The BEKK modelhas the formSilvenoinen A. and Terasvirta T. (2008):

$$H_t = C\grave{C} + \sum_{j=1}^{q}\sum_{k=1}^{k} \grave{A}_{kj} r_{t-j} \grave{r}_{t-j} A_{kj} + \sum_{j=1}^{p}\sum_{k=1}^{k} B_{kj} H_{t-j} \grave{B}_{kj}$$

Where:

A_{kj}, B_{kj} and C are N*N parameter matrices and C is triangular. Ht = [hijt] is the conditional covariance matrix of rt and rt is a N*1 stochastic vector process. q and p are ARCH and GARCH orders.

The several parameterizations that contains the above form make the estimation of the model more difficult. Thus, Engle and Kroner (1995) give conditions for eliminating redundant, observationally equivalentrepresentations.

$$H_t = C\grave{C} + \grave{A}_{kj} r_{t-j} \grave{r}_{t-j} A_{kj} + B_{kj} H_{t-j} \grave{B}_{kj}$$

Since we have only two variables and in order to restrict the number of parameters and simplify their interpretation, we use the diagonal form of the BEKK model as shown in the above matrix form.The estimated parameters of the own lagged innovations quantify the effects of "news"on the variances (ARCH effects), while the parameters of the lagged variances measure theextent of volatility clustering (GARCH effects) and thus reveal the persistence of volatility. This paper estimates the following three variance and covariance equations:

$$h_{11,t} = c_{11}^2 + a_{11}^2 r_{1,t-1}^2 + b_{11}^2 h_{11,t-1}$$

$$h_{22,t} = c_{22}^2 + a_{22}^2 r_{2,t-1}^2 + b_{22}^2 h_{22,t-1}$$

$$h_{21,t} = c_{21}^2 + a_{11}^2 a_{22}^2 r_{1,t-1}^2 r_{2,t-1}^2 + b_{11}^2 b_{22}^2 h_{11,t-1} h_{22,t-1}$$

The conditional covariance matrix H_t in MGARCH model is estimated using quasi maximum likelihood (QML) by maximizing the Gaussian log likelihood function.

The time series treated in MGARCH-BEKK should be stationary and the distribution of its residual is pre-defined as a conditional Gaussian distribution (normal).

Data:

In order to test the interrelation between oil and food volatility, monthly data have been used covering the period 1960-January to 2013-June. The returns of food and oil prices expressed in logarithm have been used. $R_t = \log\left(\frac{P_t}{P_{t\_1}}\right)$

For the food price index, we used data from the UNCTAD where this index includes: wheat, maize, rice, sugar, beef, soybean meal and fishmeal. For the crude oil prices we use the data of world Texas intermediate from the energy information administration (EIA).

4- Empirical results:

3-1 Descriptive statistics and stationarity tests:

From the histogram and descriptive statistics of the return series of food price index and oil price, we observe that the mean and the median are positive for both of the series which indicates the increasing trend of the food and oil prices during the period of the study. The positive skewness indicates that the return series is asymmetric. The Jack Bera test and its probability equals to 0 reject the hypothesis of the normal distribution which confirms that the return series is not normally distributed. (table 1).

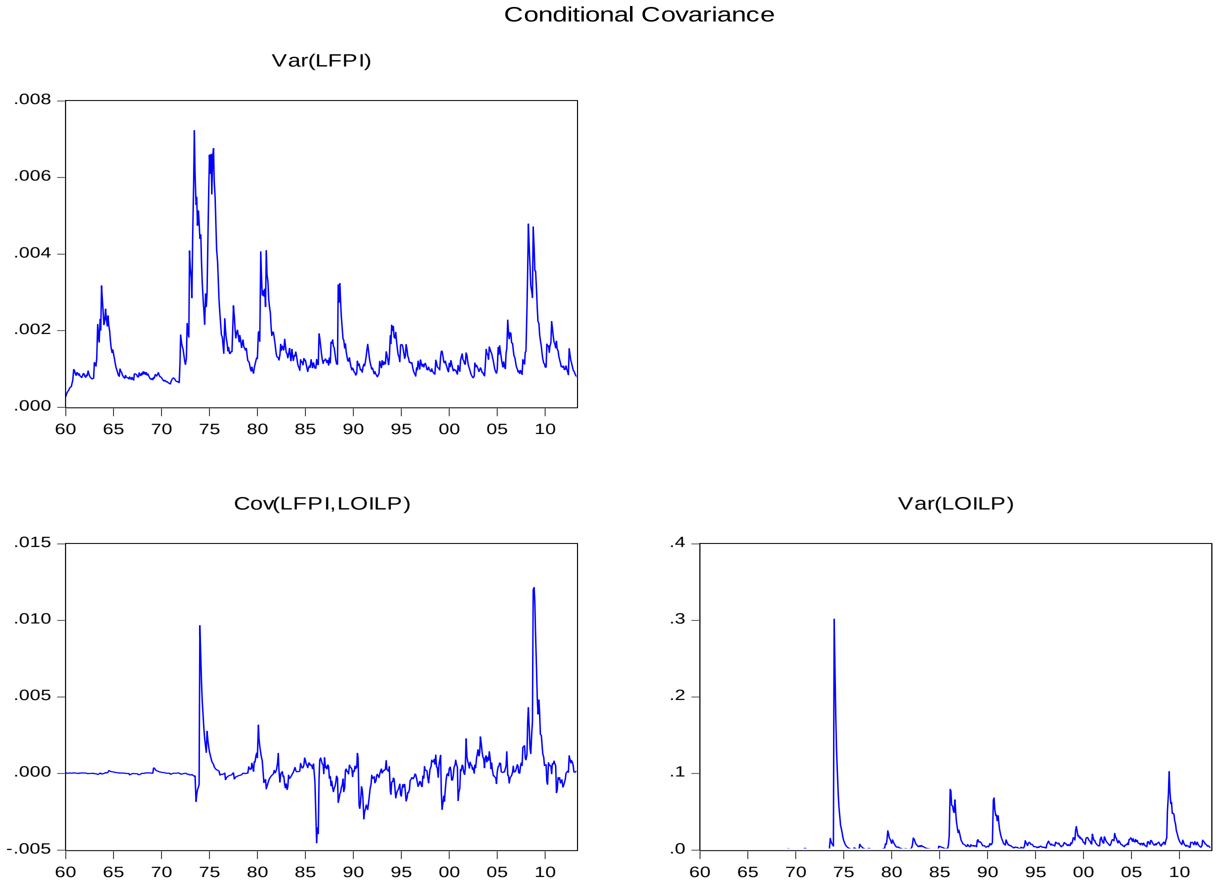
The augmented Dickey-Fuller and PhilipePerron tests for unit roots showed that either the series of food price index or the crude oil price returns are stationary in their levels; (table2), thus, we use them to estimate the GARCH models.

3-2 Diagonal BEKK- MGARCH estimation results:

The estimations results are provided in table3. It shows that most of the parameters are positive and significant indicating the existence of ARCH and GARCH effects and volatility persistence. The significant and positive parameter of h_{11} means that the current conditional variance of the food return is affected by its own previous variance in the previous time. i.e. the existence of volatility in the food market. The same is for the oil market where the second variance equation h_{22} shows significance in the volatility persistence in this market.

The covariance equation h_{21} indicates a strong positive and significant interrelation between volatilities in food and oil markets (volatility spillover); the significant parameters means that the variances in the food market is affected by the shock in the oil market (significant a_{21}) and the previous volatility (conditional variance) of the oil market (significant b_{21}) and vice versa.

In order to confirm the estimation results, the figures below plot the conditional variances of the oil and food series individually and the conditional covariance of the model.



The figures show clearly existence of the volatility clustering in the individual series. The covariance graph confirms the existence of persistent volatility among food and oil markets.

Moreover, it shows a strong impact of the oil shocks on the food market and other strong impact of the global financial crisis 2008-2009 on the two markets which confirms the interrelationship between the financial markets including the global food market.

5- Conclusion:

This paper sought to investigate in the relationship between the volatility existing in the crude oil and the global food markets.It used a multivariate GARCH type model diagonal BEKK model. The results showed strong evidence of volatility clustering in each of the markets (food and oil). The covariance equation indicated the existence of an interrelationship between food and oil markets. However, this interrelationship is not through the price levels but it is via the volatility existing in both of the markets which means that the variations in oil market spread easily to the food market. This can be explained by the important use of oil in the production of any food product; the use of biofuels and fertilizers. The volatility transmission from food to oil market can be explained by the quality of the food products used in the calculation of the index, considered as strategic goods used by financial investors.

It is evident that the findings of this study induce to dig deeper in the food price volatility issue and investigate in the potential and the causes beyond this interrelationship between oil and food volatilities in future research.

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Tables:

Table1: Descriptive statistics

	LFPI	LOILP
Mean	0.002743	0.005419
Median	0.000756	0.000000
Maximum	0.149055	0.852587
Minimum	-0.138278	-0.396009
Std. Dev.	0.039028	0.074101
Skewness	0.303495	2.009250
Kurtosis	4.883863	32.76601
Jarque-Bera	104.6266	24095.29
Probability	0.000000	0.000000
Sum	1.758473	3.473701
Sum Sq. Dev.	0.974849	3.514233
Observations	641	641

Table 2: unit root tests

	ADF	PP	Result
	level	level	
Lfood	-17.39 (0.00)	-17.37 (0.00)	I(0)
Loilp	-20.02 (0.00)	-19.57 (0.00)	I(0)

Table3: BEKK estimation results:

	c	A	b
$h_{11,t}$	$9.9*e^{-05}$ (0.0016)*	0.1167 (0.00)*	0.818 (0.00)*

$h_{22,t}$	$8.6*e^{-05}$ (0.75)	0.4114 (0.00)*	0.755 (0.00)*
$h_{21,t}$	$4.68*e^{-05}$ (0.00)*	0.219 (0.00)*	0.760 (0.00)*