Is there Co-Movement of Agricultural Commodities Futures Prices and Crude Oil?

Valeri Natanelov[a]*, Mohammad J. Alam[a§], Andrew M. McKenzie[b] and Guido Van Huylenbroeck[a]

[a]Department of Agricultural Economics, Ghent University, Ghent, Belgium

[§]Department of Agribusiness and Marketing, Bangladesh Agricultural University, Bangladesh

[b]Department of Agricultural Economics and Agribusiness, University of Arkansas, Arkansas, US

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I. INTRODUCTION

Various studies on co-movement in commodity markets have presented contradicting results. The linkages between energy and agricultural markets have recently received increased attention and have often been attributed to biofuels albeit with only questionable empirical evidence. The complexity of these issues and the narrow perspective of the analyses make it difficult for the market participants, and especially policymakers, to see the 'forest for the trees.' In this study we attempt to take a more holistic perspective on these issues. Furthermore, we make more direct use of the advantage of the price discovery role of futures markets through which supply and demand shocks and price spillovers between markets can be determined. In terms of the scope of the analysis, we are able to present a *before* and *after* perspective by looking at two periods, namely the one before and after the massive introduction of biofuels. More importantly, not only does this approach provides insight on whether linkages between markets change over longer time periods, it also offers us a relative comparison of the linkages between energy and agricultural markets before and after the exponential production of biofuels.

In concreto, we analyze the relationships between crude oil and agricultural commodities cocoa, coffee, corn, soybeans, soybean oil, wheat, rice, sugar but also gold. Gold is included in the analysis due to its representative nature. It has been and still is the most important precious metal and thus plays a unique role as a store of value particular in times of political and economic uncertainties (Aggarwal and Lucey, 2007). Thus it is of importance to analyze the cointegration relationship and causality of crude oil and gold futures to interpret the dynamics of the commodity futures markets in a macroeconomic context.

The paper is structured in the following manner. In the literature review section we attempt to offer a comprehensive overview of previous studies to outline the framework of our study. In the methodology section we discuss the techniques used in our analysis. Consequently, data construction and the rationale behind the selected time periods are presented. In the following section we present and discuss the results. In the final part concluding remarks and recommendations are offered.

II. LITERATURE REVIEW

Pindyck and Rotemberg (1990) introduce *the excess co-movement hypothesis* (ECH) between commodity prices, arguing that due to herd behavior in financial markets the prices tend to move together. Palakas and Varangis (1991) scrutinizes Pindyck and Rotemberg's results in a working paper for the World Bank. Using cointegration techniques developed by Engle and Granger (1987b) they argue that there is no excess co-movement between various commodities. Nonetheless, they find 14 out of 42 pairs to exhibit excess co-movement and acknowledge that there are problems with the used framework such as the non-reciprocity of cointegration between $X_{1,t} – X_{2,t}$ and $X_{2,t} – X_{1,t}$ and due to autocorrelation in their sample which could lead to misspecifications. Deb and Triverdi (1996) find weak evidence of excess co-movement within the framework of univariate and multivariate GARCH(1,1) models. Cashin (2009) use concordance correlation to confute ECH. Ai and Chatrath (2006) use quarterly inventory and harvest data for wheat, barley, corn, oats, and soybeans, from January 1957 to September 2002 to fit a partial equilibrium model. Dismissing the claim of excessive co-movement they ascribe much of the co-movements to common tendencies in demand and supply factors. In contrast to the studies cited above, we take a more nuanced approach on co-movement between commodities. Foremost, the concept of *excess* co-movement is a relative one and requires a point of reference. We are more concerned about parallel movement of prices between commodities futures and whether these relationships change over time, without making statements on potential excessiveness of the relationships. We analyze whether commodity future prices are linked to the price of crude oil resulting in a co-movement between crude oil and a series of commodity futures prices. Furthermore, if a herd behavior in financial markets is observable, futures markets should reflect this behavior due to the inherent nature of the speculative instruments. Since the volume of trades of crude oil futures surpasses any other commodity effortless, we focus on paired movements between crude oil futures prices and a series of agricultural commodities and gold.

The main driver for the expansion of the oil market can be traced back to the change of oil industry in 1970s (Reynolds and Kolodziej, 2007). The nationalization of Exploration and Production (E & P) in major oil producing countries decoupled the upstream and downstream (i.e. refining and distribution). The major oil companies lost access to large volumes of equity crude oil and thus were forced to buy large quantities at arm's length from the national oil companies. Consequently, the global oil market expanded swiftly. Companies started to sell and buy oil outside their network and in doing so stimulating the growth of the physical market. Decades of this system root the current situation where only a fraction of produced oil by the majors is also refined in their network.

At the same time, the price volatility of crude oil prices prompted hedging needs for market participants causing the growth of the largest derivative markets for commodities. The most notable price rally is without a doubt the rally of oil prices in late 2007 – early 2008 followed by a rapid collapse in mid-2008. The financial crisis has been blamed for this erratic price behavior of crude oil (Zhang *et al.*, 2009). Kesicki (2010) offers a more detailed picture of the most recent oil price surge. In parallel, commodities prices seem to follow the crude oil price and ostensibly its volatility to some extent. Consequently the question arises whether the co-movement is merely a short-run phenomenon opposed to a parallel movement of price series.

The excessive price fluctuations induce additional interest resulting in various studies and economic analyses in order to understand the influences and aftereffects. Biofuels draw a great deal of attention in an attempt to link the energy markets and agricultural commodities (Campiche *et al.*, 2007; Francisco and Augusto, 2009; Harri *et al.*, 2009; Hertel, 2010; Peri and Baldi, 2010; Tyner, 2009; Yu *et al.*, 2006). Even though the authors often conclude that a noticeable link is present between energy markets and agricultural commodities through biofuels no clear-cut evidence can be provided for policymakers. Since our analysis encompasses a relative comparison of a period with negligible biofuel production and a period with relatively large production, it may offer insight on the potential linkage of biofuels between agricultural and energy markets.

Energy prices affect world economies and markets through profuse manners. Higher energy prices cascade down to increased production costs in the mid- and long term. Consequently, processing and transportation follow (von Braun *et al.*, 2008). In addition to direct impacts of changing energy prices the commodities markets are affected through macro-economic effects (Gohin and Chantret, 2010). Uri (1996) indicated the effect of changes in the price of crude oil on agricultural employment in the USA between 1947 and 1995 using Granger Causality. Lardic and Mignon (2008) studied the long-term relationship between oil prices and economic activity, proxied by GDP, for the US, G7, Europe and Euro area economies. While rejecting standard cointegration, they find evidence for asymmetric cointegration between oil prices and GDP indicating that rising oil prices seem to retard aggregate economic activity further than falling oil prices stimulate it. Correspondingly, He (2010) established a cointegration relationship between real futures crude oil prices and global economic activity, using the Kilian index. Crude oil markets even seem to affect, be it through an irregular relationship, the stock markets (Ciner, 2001; Ghouri, 2006; Miller and Ratti, 2009; Papapetrou, 2001). Various other studies suggest that crude oil prices have a statistically significant effect on economic activity (Adrangi *et al.*, 2001; Berument *et al.*, 2010; Brown and Yücel, 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). This paper complements these studies through investigation of direct linkages between crude oil and agricultural futures. In addition, our study analyses whether certain relationships change over long(er) time periods.

The effects of energy prices and crude oil in particular on commodities futures seem to be complicated and multifaceted. Gohin and Chantret (2010) measure the long-run impact of energy prices on world agricultural markets including macro-economic linkages. By incorporating a general equilibrium (GE) model they find a significant relationship. Besides identifying a positive relationship due to the cost push effect, they find that the introduction of the real income effect may imply a negative relationship between world food and energy prices.

Baffes (2007) argues that if crude oil prices remain high then the food commodity price boom is expected to continue much longer. Plourde and Watkins (1998) compare crude oil volatility to a series of commodities. Their results imply that short-term price volatility of various commodities, among which are wheat and gold, has tended to be lower than that for oil. However the volatility of crude oil does not seem to be a clear outlier.

Taken the above studies into account, it is of little surprise that crude oil futures might have an impact on the prices of other commodity futures markets. As mentioned before, if herd behavior is present in the commodity futures markets, crude oil futures is seemingly a proper starting point for analysis. However, the notion that traders, for no apparent reason, take similar positions for different commodities is a stern premise, one which we are not prepared to make. In the light of the above, we base our analysis upon the fact that crude oil might be a catalyst for traders to make decisions about their positions on other commodity markets. Due to the complexity of inter-relations between crude oil and various commodities and the whole economy, traders might excessively transfer price movements from one market to the other. That being said, trading behavior might change in different economic environments. We attempt to uncover potential changes in trading behavior and linkages between markets through a simple setup and framework of our analysis.

III. METHODOLOGY

Johansen co-integration

In the case of non-stationarity of the time-series, cointegration provides appropriate statistical techniques to investigate if there is a statistically significant relationship between the non- stationary time-series. Therefore we test the price series for stationarity at the level and consequently at their first differences. In time series econometrics, it is said that prices are integrated of order one denoted by $P_t \sim I(1)$ and prices are integrated of order zero denoted by $\Delta P_t \sim I(0)$. When price series are found to be non-stationary at the level but stationary at their first difference cointegration test may be applied. The cointegration procedure is based upon an unrestricted vector autoregressive (VAR) model specified in error-correction form (Johansen (1988) and Johansen and Juselius (1990)):

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \, \Delta X_{t-i} + \Phi D_t + v_t \quad (1)$$

Where X_t includes all n variables of the model which are $\sim I(1)$, the Π, Γ_i and Φ are parameter matrices to be estimated, D_t is a vector with deterministic elements (constant, trend and dummy) and v_t is a vector of random errors which follow a Gaussian white noise process. Equation (1) implies that there can never be any relationship between a variable with a stochastic trend, $I(1)$ and a variable without a stochastic trend, $I(0)$. So, if $\Delta P_t \sim I(0)$, then Π will be a matrix of zeros, except when a linear combination of the variables in P_t is stationary. The Johansen test for cointegration evaluates the rank (r) of the matrix Π. If r = 0, all variables are I(1) and thus not cointegrated. In case 0 < r < N, there exist r cointegrating vectors. In the third case, if r = N all the variables are I(0) and thus stationary, and any combination of stationary variables will be stationary. Π represents the long response matrix and is defined as the product of two matrices: α and β', of dimension (g x r) and (r x g) respectively. The β matrix contains the long-run coefficients of the cointegrating vectors; α is known as the adjustment parameter matrix and is similar to an error correction term. The linear combination(s) $\beta' x_{t-k}$ of this matrix will be I(0) in the case where the times series are cointegrated. In other words, if rank of Π = r = K, the variables in levels are stationary meaning that no integration exist; if rank Π = r = 0, denoting that all the elements in the adjustment matrix have zero value. Therefore, none of the linear combinations are stationary. According to the Granger representation theorem (Engle and Granger, 1987a), when K > 0 and rank of Π (r) < K, there are r cointegrating vectors or r stationary linear combinations of the variables. The Johansen cointegration method estimates the Π matrix through an unrestricted VAR and tests whether one can reject the restriction implied by the reduced rank of Π. Two methods of testing for reduced rank of Π are the trace test and the maximum eigenvalue, respectively:

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \ln(1-\hat{\lambda}^2{}_i) \quad (2)$$

$$\lambda_{max}(r, r+1) = -T\ln(1-\lambda_{r+1}) \quad (3)$$

Where, λ_i is the estimated values of the ordered eigenvalues obtained from the estimated matrix and T is the number of the observations after the lag adjustment. The trace statistics test the null hypothesis that the number of distinct cointegrating vectors (r) is less than or equal to r against a general alternative. The maximal eigenvalue tests the null that the number of cointegrating vectors is r against the alternative of r +1 cointegrating vectors.

Causality from vector error correction model (VECM)

The existence of cointegration in the bi-variate relationship implies Granger causality at least in one direction which under certain restrictions can be tested within the framework of Johansen cointegration by the Wald test (Dolado and Lütkepohl, 1996; Mosconi and Giannini, 1992). If the α matrix in the cointegration matrix (Π) has a complete column of zeros, no casual relationship exist since no cointegrating vector appears in that particular block. Pair wise causal relationship can be represented through the following equation:

$$\begin{bmatrix}\Delta X_{1,t}\\ \Delta X_{2,t}\end{bmatrix} = \begin{bmatrix}\mu_1\\ \mu_2\end{bmatrix} + \begin{bmatrix}\alpha_1\\ \alpha_2\end{bmatrix}\left(X_{1,t-1} - \beta X_{2,\ t-1}\right) + A_1\begin{bmatrix}\Delta X_{1,t-1}\\ \Delta X_{2,t-1}\end{bmatrix} + \cdots A_k\begin{bmatrix}\Delta X_{1,t-k}\\ \Delta X_{2,t-k}\end{bmatrix} + \begin{bmatrix}v_{1t}\\ v_{2t}\end{bmatrix} \quad (4)$$

Parameters contained in matrices A_k measure the short run causality relationship, while β is the cointegrating parameter that characterizes the long run equilibrium relationship between the series. Through equation (4), three possibilities for long-run causality may be identified, i) $\alpha_1 \neq 0$, $\alpha_2 \neq 0$; ii) $\alpha_1 = 0$, $\alpha_2 \neq 0$, and iii) $\alpha_1 \neq 0$, $\alpha_2 = 0$. The first case indicates bi-directional causality, while the second and third imply uni-directional causality.

To analyze for short-run causality we apply the Wald test with the null hypothesis that the joint contribution of the lags of endogenous variables is not equal to zero. If the null is cannot be rejected it implies that the respective endogenous variables can be treated as exogenous in the system. In case of bi-variate models, the Johansen cointegration equation (1) can be rewritten as:

$$\Delta X_{1,t=}\mu_1 + \sum_{i=1}^{k1} \beta_i \Delta X_{1,t-i} + \sum_{j=1}^{k2} \beta_j \Delta X_{2,t-j} + \alpha_1 ECT_{t-1} + \varepsilon_{t,1} \qquad (5)$$

$$\Delta X_{2,t=}\mu_2 + \sum_{i=1}^{k1} \beta_i \Delta X_{1,t-i} + \sum_{j=1}^{k2} \beta_j \Delta X_{2,t-j} + \alpha_2 ECT_{t-1} + \varepsilon_{t,1} \qquad (6)$$

where, $X_{1,t}$ and $X_{2,t}$ are time series (of prices) and ECT is the error correction term. We test the short run causality through equations (5) and (6), by examining the significance of all lagged dynamic terms.

Threshold Cointegration

Threshold cointegration allows for the extension of the classical case of linear cointegration. The adjustment from equilibrium may take place only after the deviation exceeds a certain threshold. Through the perspective of economic theory, the assumption of non-linearity may not be valid in the presence of transaction costs (Balke and Fomby, 1997) or certain policies (Lo and Zivot, 2001) that may influence and buffer markets until the deviations exceed a certain threshold. Threshold cointegration analysis may indicate that once a threshold level is surpassed, prices will adjust back to a long-run equilibrium.

Following Hansen and Seo (2002) a two-regime threshold cointegration model takes the form

$$\Delta X_t = \begin{cases} B'_1\, X_t + \mu_t & \text{if} \quad \beta' X_{t-1} \leq \gamma \\ B'_2\, X_t + \mu_t & \text{if} \quad \beta' X_{t-1} > \gamma \end{cases} \qquad (7)$$

where γ represents the threshold parameter. Equation (7) can be written as

$$\Delta X_t = B'_1\, X_{t-1}(\beta) d_{1t}(\beta, \gamma) + B'_2\, X_{t-1}(\beta) d_{2t}(\beta, \gamma) + \mu_t \qquad (8)$$

with $d_{1t}(\beta, \gamma) = 1$ (if $\beta' X_{t-1} \leq \gamma$) and $d_{2t}(\beta, \gamma) = 1$ (if $\beta' X_{t-1} > \gamma$) and with coefficient matrices B_1 and B_2 determining the dynamics in the two regimes. Besides the coingrating vector β, all coefficients are permitted to switch between the two regimes.

Hansen and Seo note that the threshold effect is only consistent if $0 < P(\beta' X_{t-1} \leq \gamma) < 1$, otherwise the model would reduce to a linear cointegration model. This constraint is imposed by assuming

$$\pi_0 \leq P(\beta' X_{t-1} \leq \gamma) \leq 1 - \pi_0 \qquad (9)$$

where $\pi_0 > 0$ is a trimming parameter. In the empirical application $\pi_0 = 0.05$ to ensure sufficient sample variation for every alternative of γ. The estimation of model (8) is conducted through maximum likelihood, under the assumption of iid Gaussian errors.

The Hansen and Seo (2002) threshold model has the hull hypothesis of no threshold against the alternative hypothesis of linear cointegration. However, in our analysis we are interested to apply threshold cointegration model in case we cannot find linear cointegration. Seo (2006) offers a test which would complement our analysis and enables us to conclude on the consistency of the results. In his paper, Seo offers a test of no cointegration versus threshold cointegration based on a Band - Threshold Vector Error Correction Model (TVECM) as specified in equation (8):

$$\Delta X_t = \delta_1(\gamma) d_{1t}(\beta, \gamma) + \delta_2(\gamma) d_{2t}(\beta, \gamma) + \mu(\gamma) + \phi_1(\gamma) \Delta X_{t-1} + \cdots + \phi_q(\gamma) \Delta X_{t-q} + \varepsilon_t(\gamma) \quad (10)$$

where ϕ is a qth-order polynomial in the lag operator defined as $I - \phi_1 - \ldots - \phi_q$. For a detailed description we refer to Seo's (2006) paper.

DATA

The data used in the empirical analysis comprises monthly futures prices of crude oil, cocoa, coffee, corn, soybeans, soybean oil, wheat, rice, sugar and gold starting July 1989 until February 2010. Monthly prices for the nearest futures contracts[1] are analyzed. To account for the problem of comparing disparate price units, the data is indexed based on the price of August 1999 for each commodity respectively. Previous studies on co-movement have only focused on lengthy periods of several decades. In contrast, after analyzing for the full period, we break down our sample in 2 periods. Based on versatile information we chose January 2002 as the breakpoint for our analysis. Various reasons may be behind the structural change of price movements in 2002, such as depreciation of US dollar, global inflation, oil supply manipulation by OPEC and various geopolitical events (Zhang and Wei, 2010). Furthermore, this breakpoint allows us to analyze whether exchange-traded funds (ETFs), which bind a basket of commodities, have an influence on the co-movement of prices. Through the Quarterly Index Investment Data[2] reports of the Commodity Futures Trading Commission (CFTC) one can observe increase in momentum of the ETFs from 2002, ranging from \$12 billion and growing steadily to up to \$200 billion in 2008 and more recently to \$160 billion in 2010.

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[1] Crude Oil (Brent), CB; Cocoa (Ivory Coast), CC; Coffee (Colombian), KC; Sugar (#11/World Raw), SB: *Intercontinental Exchange (ICE)*
Corn (No. 2 Yellow), C-; Soybeans (No. 1 Yellow), S-; Soybean Oil, BO; Wheat (No. 2 Soft Red), W-; Rice (No. 2 Rough) RR; *Chicago Board of Trade (CBOT)* part of *CME Group*
Gold, GC: New York Mercantile Exchange *(*NYMEX) part of *CME Group*

[2] http://www.cftc.gov/MarketReports/IndexInvestmentData/index.htm

Next to that, our analysis may shed some light on how the ethanol market's growth, induced by policy in the past decade, might affect the co-movement of crude oil and agricultural commodities such as corn, soybeans and soybean oil. Past studies using cointegration methods seem to come short in offering convincing results. Campiche (2007) examined the co-variability between crude oil prices and corn, sorghum, sugar, soybeans, soybean oil, and palm oil prices during 2003-2007 through Johansen cointegration tests. The analysis revealed no cointegrating relationships. Only after fragmenting the full period into 2006-2007 times period soybean and corn prices were found to be cointegrated with crude oil. Yu (2006) analyzes weekly data between 1999-2006 of soybean oil, sunflower oil, rapeseed oil, palm oil (US$/ton) and crude oil (US$/barrel). Cointegration analysis of 2 commodities with differing units may present spurious results. Since ethanol production started to increase exponentially from 2002 onward, our analysis of the before and after period will provide a more clear picture of a potential link between the markets. For sake of simplicity we will refer to the 1989M07-2010M02 period as the full period; the 1993M11-2001M12 period as the first period ; and 2002M01-2010M02 as the second period.

IV. RESULTS AND DISCUSSION

To determine whether the series are stationary, the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test are carried out. For all time series the tests point to the existence of one unit root I(1)[3]. Thus, the difference of each time series can be regarded as stationary. In order to identify a possible influence of crude oil on various commodities, each time series was paired with crude oil, providing us with 9 bivariate systems. Since the time series are integrated of the same order, cointegration techniques can be used to determine whether a stable long-run relationship exists between each pair. Johansen's tests for cointegration are performed. The VAR specification is estimated by applying one to 12 lags. The Likelihood Ratio (LR) criterion was utilized to select optimal lag length.

Tables 1. shows summary results for the full period (1989-2010), first period (1993-2001) and second period (2002-2010) respectively. The trace and maximum eigenvalues tests are based on likelihood ratio from the estimated restricted VAR model. Table 1 offers a summary of the results comparing the three analyses. The results indicate that cocoa, wheat and gold are cointegrated over the full period, which implies that the prices of these commodities move together with crude oil in the long run. The results of the first and second period are consistent with the full period for cocoa, wheat and gold. In the first period, we observe cocoa, soybeans, soybean oil, wheat, corn and gold futures to be cointegrated with crude oil futures. In the second period however we only observe coffee besides cocoa, wheat and gold, to be cointegrated with crude oil. The contrast between the first and second period is remarkable and further analysis seems to be required.

Table 1: Summary of the bi-variate Johansen cointegration rank tests

	1989 - 2010 Period	**1993-2001 Period**	**2002-2010 Period**
Crude Oil vs	r = 1	r = 1	r = 1
Cocoa	**not rejected**	**not rejected**	**not rejected**
Rough Rice	rejected	rejected	rejected
Soybeans	rejected	**not rejected**	rejected
Soybean Oil	rejected	**not rejected**	rejected
Wheat	**not rejected**	**not rejected**	**not rejected**
Corn	rejected*	**not rejected**	rejected
Coffee	rejected	rejected	**not rejected**
Sugar	rejected	rejected	rejected
Gold	**not rejected**	**not rejected**	**not rejected**

[3] Detailed results are available on request

The coffee market exhibits opposite traits. It seems that in the second period the coffee futures prices follow crude oil futures. This change of price movements may be attributed to the coffee market liberalization, which began in the '90s and continued throughout the decade (Akiyama, 2001).

Gold futures are found to be cointegrated with crude oil futures throughout the full period. Our results are consistent with previous studies (Zhang and Wei, 2010). For two markets, rough rice and sugar, the results indicated no trace of linear cointegration. The rough rice futures market is relatively new compared to the well-established futures markets for corn, wheat, and soybeans and rice industry participants have referred to the rice futures market as a thinly traded futures market (McKenzie, 2002). It seems that in case of rough rice, the futures market seem to exhibit problems unrelated to macroeconomic factors. Sugar futures seem to have a quasi-independent movement from crude oil. Further study is required to analyze that specific market.

Consequently, Table 2 integrates the estimates of the parameter estimates; the speed of adjustment from the estimated Johansen VAR (restricted VAR model); t-tests for the cointegrating vector and the speed of adjustment. The main highlight of the results of the full period is the relatively larger parameter estimate (β) of gold –crude oil pair. This implies that crude oil and gold are strongly linked. The estimates of the first period are consistent, with soybean having a relatively lower β. The linkage between soybeans is expected to be relatively weaker than with soybean oil. For the second period, the main observation is that the β estimate for coffee is relatively small. Figure 7 confirms that the movement between crude oil and coffee futures is relatively weak. The error correction estimates are fairly consistent throughout the 3 analyses. The ECT for gold in the full period is relatively small, which confirms the strong relationship between the two commodities. In the first period we observe that ECT of soybeans and soybean oil pairs is relatively larger. ECT of coffee model in the second period is relatively larger, which is consistent with the previous results and the context of that market.

Once cointegration between time series is established it is of interest to analyze for causality of each cointegrating pair. Long run causality from the estimated Johansen VECM is analyzed through a likelihood ratio (LR) test by restricting the disequilibrium error term. Table 3 presents the results of these tests. The results of the first period indicate that cocoa, soybeans, wheat, corn, sugar and gold futures precede crude oil futures. In case of soybean oil we find bi-directional causality, however the probability level of soybean influencing crude oil is 0.08. It may seem out of the ordinary for crude oil futures price to be *led* by other commodities. However, one must keep in mind that causality indicates no more than one series preceding the other. In the literature review section we have established that crude oil prices are linked with the economies and that the price movements of crude oil could be supply or demand driven. Thus our results indicate that in the first period crude oil price movements were mainly demand driven and mainly pushed by economic activity. The results of the second period are more muddled with crude oil futures preceding cocoa and gold futures, while wheat and coffee futures precede crude oil futures. This implies a more chaotic situation in the market, which may be attributed to political and economic uncertainties.

Corn, soybeans and soybean oil seem to seize their co-movement with crude oil after 2002. Scrutinizing pltted price data shows that besides the peak of 2008 these commodities futures do not seem to have a close relationship with crude oil. Nonetheless, due to developments in the past decade linked to biofuel implementation, it is of interest to look closer into these three bivariate systems. Since the Johansen test, investigates linear cointegration it is appropriate to consider asymmetric cointegration for these pairs. Hansen and Seo (2002) offer a model to test for threshold cointegration. The null hypothesis of the test is linear cointegration, versus threshold cointegration. Considering that we rejected the hypothesis of linear (Johansen) cointegration it is likely that we might a priori find results for threshold cointegration. To keep our analysis consistent, we implement the Seo (2006) test, with the null of no-cointegration versus threshold cointegration. Consequently, we implement the Hansen and Seo (2002) model to obtain the threshold values for the significant pair(s). We use data between January 2000 and February 2010 for the threshold cointegration analysis.

Table 4 shows the results of the test of no cointegration versus threshold cointegration. We observe that only in case of *crude oil – corn pair* no cointegration can be rejected at a significant level. These results seem to be consistent with general expectations that interaction between crude oil and corn is relatively stronger through the biofuel production linkage. Furthermore, it should not come as a surprise that linear cointegration was rejected for crude oil - corn bivariate system. Lo and Zivot (2001) notice that cointegration is not found for goods subject to policy intervention. Simple calculations with the 2010 data from Food and Agricultural Policy Research Institute (FAPRI) indicate that 32% of total US corn production corn was allocated to ethanol production. Furthermore, 98% of total ethanol production was dependent on corn. The biofuel market is an artificial market and its production was mainly imposed by governments. The Energy Policy Act of 2005 established the renewable fuel standard starting at 4 billion gallons in 2006 and rising to 7.5 billion in 2012. The Energy Independence and Security Act of 2007 established a renewable fuel standard totaling 36 billion gallons (1billion biodiesel) by 2022.

The subsidies offered throughout the production chain of biofuels affect the demand and thus the prices of agricultural commodity prices of corn. Due to influx of government funds in biofuels-production this reallocation of resources is less dependent on energy prices or the economic situation as a whole. In this context we apply the threshold cointegration methodology to control whether such a situation can be empirically verified. The following shows the estimates of the TVECM, with gamma value of 0.38.

$$\begin{pmatrix} \Delta\text{Crude Oil}_t \\ \Delta\text{Corn}_t \end{pmatrix} = \begin{cases} \begin{pmatrix} -0.08 \\ 0.02 \end{pmatrix} \text{ECT}_{-1} + \begin{pmatrix} -0.07 \\ 0.02 \end{pmatrix} + \begin{pmatrix} 0.20 & -0.10 \\ -0.07 & -0.15 \end{pmatrix} \begin{pmatrix} \Delta\text{Crude Oil}_{t-1} \\ \Delta\text{Corn}_{t-1} \end{pmatrix} \leq 0.38 \\ \begin{pmatrix} -0.09 \\ 0.05 \end{pmatrix} \text{ECT}_{-1} + \begin{pmatrix} 0.23 \\ -0.15 \end{pmatrix} + \begin{pmatrix} 0.57 & 0.58 \\ 0.19 & 0.25 \end{pmatrix} \begin{pmatrix} \Delta\text{Crude Oil}_{t-1} \\ \Delta\text{Corn}_{t-1} \end{pmatrix} > 0.38 \end{cases}$$

The percentage of observation in each regime is 68.3 and 31.7 respectively. Figure 11 shows the grid search of threshold parameter γ and the LM statistics of the ECT values. Keeping in mind that the count of observation in each regime is not a continuous one we need to examine the results of the TVECM properly in order to interpret the threshold cointegration in an economic context. To find the value of the crude oil price above which the corn prices resume co-movement, we need to consider the TVECM results in parallel with the prices of the two commodities. In Figure 12 we plot (indexed) price values of the two commodities and $\Delta\widehat{\text{Crude Oil}}_t$ of the TVECM of the upper threshold (i.e. the regime where we find threshold cointegration). First and foremost we note that between April and July 2004 the futures prices of corn seem to adjust to news of the Energy Policy Act of 2005. Especially in futures markets traders tend to adjust their positions as soon as the news is made public. Furthermore, by looking at Figure 12, it is noticeable that between mid 2004 until July 2006 the futures prices of corn do not move together with crude oil due to policy interventions on biofuels. This is consistent with our results as we do not find linear nor threshold cointegration. Moreover we find confirmation of our results in Campiche’s (2007) paper. In his analysis of 2003-2007 period, cointegration was only found in the 2006-2007 period. It seems that at a certain point - July 2006 - crude oil futures prices surpassed a certain threshold (Figure 12) - 75 $/barrel - after which the corn market resumed co-movement with crude oil.

V. CONCLUSIONS

This paper offers a comprehensive study on the interaction between crude oil futures market and cocoa, coffee, corn, soybeans, soybean oil, wheat, rice, sugar and gold futures markets. To provide insight on recognizing and analyzing the dynamics of crude oil futures market, gold futures market and the whole large agricultural commodities markets, the concept of co-movement (i.e. price cointegration) and price causality of markets is analyzed. Once more we highlight that futures prices by definition incorporate all available information and thus are more appropriate to identify supply and demand shocks and price spillovers than real prices. That being said, a similar analysis with spot price could yield different results. Furthermore, we scrutinize two distinct time periods set apart by various economic and geopolitical events. Through this relative comparison we can make conclusions about evolution in price movements without carrying the burden of making absolute statements.

Through use of cointegration methodologies we have shown that co-movement of commodity prices is a temporal concept and should be treated accordingly. Parallel movement between crude oil and cocoa, wheat and gold pairs have been found for the past two decades, which indicates strong linkages between crude oil and these markets. Looking at the two split periods separately, we find confirmation that coffee exhibits co-movement with crude oil after the liberalization of the coffee markets. In case of soybeans, soybean oil and corn especially the results indicate that biofuel policy has buffered the price relationship between those markets and crude oil futures, be it until crude oil prices surpass a certain threshold level. An in depth focus on the crude oil – corn relationship through threshold cointegration methods revealed that biofuel policy buffers the co-movement of the two markets until crude oil futures prices rise to a level of 75$/barrel or higher.

In general we can conclude that mature and well established commodity futures markets exhibit co-movement with crude oil in the long run. However we must note that policy interventions, changing weather patterns, economic crises, changes in price interactions, geopolitics, and rising global population not only increase uncertainty and volatility, but instigate change and increase the complexity of price dynamics between crude oil and agricultural commodities. By understanding better the mechanisms behind these dynamics, better policy measures could be put in place to optimize and stabilize the markets.

REFERENCES

Adrangi, B., A. Chatrath, K. K. Dhanda and K. Raffiee (2001). 'Chaos in oil prices? Evidence from futures markets', *Energy Economics*, vol. **23**(**4**), pp. 405-425.

Aggarwal, R. and B. M. Lucey (2007). 'Psychological barriers in gold prices?', *Review of Financial Economics*, vol. **16**(**2**), pp. 217-230.

Ai, C. R., A. Chatrath and F. Song (2006). 'On the comovement of commodity prices', *American Journal of Agricultural Economics*, vol. **88**(**3**), pp. 574-588.

Akiyama, T. (2001) Title', in (Editor Ed.)^Eds.), *Book Title|,* pp. Pages|, Edition ed.|, City|: Publisher|.

Antonio, F. D. Narzo, J. L. Aznarte and M. Stigler (2009). *tsDyn: Time series analysis based on dynamical systems theory*.

Baffes, J. (2007). 'Oil spills on other commodities', *Resources Policy*, vol. **32**(**3**), pp. 126-134.

Balke, N. S. and T. B. Fomby (1997). 'Threshold cointegration', *International Economic Review*, vol. **38**(**3**), pp. 627-645.

Berument, M. H., N. B. Ceylan and N. Dogan (2010). 'The Impact of Oil Price Shocks on the Economic Growth of Selected MENA Countries', *Energy Journal*, vol. **31**(**1**), pp. 149-176.

Brown, S., P. A. and M. Yücel, K. (2001) *Energy prices and aggregate economic activity: an interpretive survey*, Federal Reserve Bank of Dallas. Available at http://ideas.repec.org/p/fip/feddwp/0102.html.

Campiche, J. L., H. L. Bryant, J. W. Richardson and J. L. Outlaw (2007) *Examining the Evolving Correspondence Between Petroleum Prices and Agricultural Commodity Prices*, American Agricultural Economics Association (New Name 2008: Agricultural and Applied Economics Association). Available at http://ideas.repec.org/p/ags/aaea07/9881.html.

Cashin, A., M. Carey, N. Watson, G. Clark, C. Newman and C. D. Waters (2009). 'Ultimate doctor liability: A myth of ignorance or myth of control?', *Collegian*, vol. **16**(**3**), pp. 125-129.

Ciner, C. (2001). 'Energy shocks and financial markets: Nonlinear linkages', *Studies in Nonlinear Dynamics and Econometrics*, vol. **5**(**3**), pp. 203-212.

Costantini, V. and C. Martini (2010). 'The causality between energy consumption and economic growth: A multi-sectoral analysis using non-stationary cointegrated panel data', *Energy Economics*, vol. **32**(**3**), pp. 591-603.

Deb, P., P. K. Trivedi and P. Varangis (1996). 'The excess co-movement of commodity prices reconsidered', *Journal of Applied Econometrics*, vol. **11**(**3**), pp. 275-291.

Dolado, J. J. and H. Lütkepohl (1996). 'Making wald tests work for cointegrated VAR systems', *Econometric Reviews*, vol. **15**(**4**), pp. 369-386.

Engle, R. F. and C. W. J. Granger (1987a). 'Co-integration and Error Correction: Representation, Estimation, and Testing', *Econometrica*, vol. **55**(**2**), pp. 251-276.

Engle, R. F. and C. W. J. Granger (1987b). 'Cointegration and Error Correction - Representation, Estimation, and Testing', *Econometrica*, vol. **55**(**2**), pp. 251-276.

Fofana, I., M. Chitiga and R. Mabugu (2009). 'Oil prices and the South African economy: A macro-meso-micro analysis', *Energy Policy*, vol. **37**(**12**), pp. 5509-5518.

Francisco, P. and R.-M. Augusto (2009) *The emergence of biofuels and the co-movement between crude oil and agricultural prices*, Department of Economics and Business, Universitat Pompeu Fabra. Available at http://ideas.repec.org/p/upf/upfgen/1174.html.

Ghouri, S. S. (2006). 'Assessment of the relationship between oil prices and US oil stocks', *Energy Policy*, vol. **34**(**17**), pp. 3327-3333.

Gohin, A. and F. Chantret (2010). 'The long-run impact of energy prices on world agricultural markets: The role of macro-economic linkages', *Energy Policy*, vol. **38**(**1**), pp. 333-339.

Hamilton, J. D. (2009a). 'Causes and Consequences of the Oil Shock of 2007-08', *Brookings Papers on Economic Activity*(**1**), pp. 215-283.

Hamilton, J. D. (2009b). 'Understanding Crude Oil Prices', *Energy Journal*, vol. **30**(**2**), pp. 179-206.

Hanabusa, K. (2009). 'Causality relationship between the price of oil and economic growth in Japan', *Energy Policy*, vol. **37**(**5**), pp. 1953-1957.

Hansen, B. E. and B. Seo (2002). 'Testing for two-regime threshold cointegration in vector error-correction models', *Journal of Econometrics*, vol. **110**(**2**), pp. 293-318.

Harri, A., L. Nalley and D. Hudson (2009). 'The Relationship between Oil, Exchange Rates, and Commodity Prices', *Journal of Agricultural and Applied Economics*, vol. **41**(**02**).

He, Y., S. Wang and K. K. Lai (2010). 'Global economic activity and crude oil prices: A cointegration analysis', *Energy Economics*, vol. **32**(**4**), pp. 868-876.

Hertel, T., Beckman, J. (2010) Commodity Price Volatility in the Biofuel Era: An Examination of the Linkage between Energy and Agricultural Markets', in (Editor Ed.)^Eds.), *Book Commodity Price Volatility in the Biofuel Era: An Examination of the Linkage between Energy and Agricultural Markets*, City.

Hsing, Y. (2007). 'Impacts of higher crude oil prices and changing macroeconomic conditions on output growth in Germany ', *International Research Journal of Finance and Economics*(**11**).

Huang, R. D., R. W. Masulis and H. R. Stoll (1996). 'Energy shocks and financial markets', *Journal of Futures Markets*, vol. **16**(**1**), pp. 1-27.

Jayaraman, T. K. and C. K. Choong (2009). 'Growth and oil price: A study of causal relationships in small Pacific Island countries', *Energy Policy*, vol. **37**(**6**), pp. 2182-2189.

Jiao, F. Y. and J. Ma (2006). 'Energy prices and aggregate economic activity: evidence from China', *Proceedings of the 2006 International Conference on Management Science & Engineering (13th), Vols 1-3*, pp. 1917-1922.

Jones, D. W., P. N. Leiby and I. K. Paik (2004). 'Oil price shocks and the macroeconomy: What has been learned since 1996', *Energy Journal*, vol. **25**(**2**), pp. 1-32.

Kesicki, F. (2010). 'The third oil price surge - What's different this time?', *Energy Policy*, vol. **38**(**3**), pp. 1596-1606.

Lardic, S. and V. Mignon (2008). 'Oil prices and economic activity: An asymmetric cointegration approach', *Energy Economics*, vol. **30**(**3**), pp. 847-855.

Lo, M. C. and E. Zivot (2001). 'Threshold cointegration and nonlinear adjustment to the law of one price', *Macroeconomic Dynamics*, vol. **5**(**4**), pp. 533-576.

Mackinnon, J. G. (1996). 'Numerical distribution functions for unit root and cointegration tests', *Journal of Applied Econometrics*, vol. **11**(**6**), pp. 601-618.

McKenzie, A. M., B. Jiang, H. Djunaidi, L.A. Hoffman, and E.J. Wailes (2002). 'Unbiasedness and Market Efficiency Tests of the U.S. Rice Futures Market', *Review of Agricultural Economics*, vol. **24**(**2**), pp. 474-493.

Miller, J. I. and R. A. Ratti (2009). 'Crude oil and stock markets: Stability, instability, and bubbles', *Energy Economics*, vol. **31**(**4**), pp. 559-568.

Mosconi, R. and C. Giannini (1992). 'Noncausality in Cointegrated Systems - Representation Estimation and Testing', *Oxford Bulletin of Economics and Statistics*, vol. **54**(**3**), pp. 399-417.

Newey, W. K. and K. D. West (1994). 'Automatic Lag Selection in Covariance-Matrix Estimation', *Review of Economic Studies*, vol. **61**(**4**), pp. 631-653.

Odusami, B. O. (2010). 'To consume or not: How oil prices affect the comovement of consumption and aggregate wealth', *Energy Economics*, vol. **32**(**4**), pp. 857-867.

Oladosu, G. (2009). 'Identifying the oil price-macroeconomy relationship: An empirical mode decomposition analysis of US data', *Energy Policy*, vol. **37**(**12**), pp. 5417-5426.

Palaskas, T. B. and P. N. Varangis (1991) *Is there excess co-movement of primary commodity prices? A co-integration test*, The World Bank. Available at http://econpapers.repec.org/RePEc:wbk:wbrwps:758.

Papapetrou, E. (2001). 'Oil price shocks, stock market, economic activity and employment in Greece', *Energy Economics*, vol. **23**(**5**), pp. 511-532.

Peri, M. and L. Baldi (2010). 'Vegetable oil market and biofuel policy: An asymmetric cointegration approach', *Energy Economics*, vol. **32**(**3**), pp. 687-693.

Pindyck, R. S. and J. J. Rotemberg (1990). 'The Excess Co-Movement of Commodity Prices', *Economic Journal*, vol. **100**(**403**), pp. 1173-1189.

Plourde, A. and G. C. Watkins (1998). 'Crude oil prices between 1985 and 1994: how volatile in relation to other commodities?', *Resource and Energy Economics*, vol. **20**(**3**), pp. 245-262.

Rafiq, S., R. Salim and H. Bloch (2009). 'Impact of crude oil price volatility on economic activities: An empirical investigation in the Thai economy', *Resources Policy*, vol. **34**(**3**), pp. 121-132.

Reynolds, D. B. and M. Kolodziej (2007). 'Institutions and the supply of oil: A case study of Russia', *Energy Policy*, vol. **35**(**2**), pp. 939-949.

Seo, M. (2006). 'Bootstrap testing for the null of no cointegration in a threshold vector error correction model', *Journal of Econometrics*, vol. **134**(**1**), pp. 129-150.

Tyner, W. (2009) The Integration of Energy and Agricultural Markets', in (Editor Ed.)^Eds.), *Book The Integration of Energy and Agricultural Markets*, City.

Uri, N. D. (1996). 'Changing crude oil price effects on US agricultural employment', *Energy Economics*, vol. **18**(**3**), pp. 185-202.

von Braun, J., A. Ahmed, K. Asenso-Okyere, S. Fan, A. Gulati, J. Hoddinott, R. Pandya-Lorch, M. W. Rosegrant, M. Ruel, M. Torero and T. van Rheenen (2008) *High food prices: The what, who, and how of proposed policy actions*, International Food Policy Research Institute (IFPRI). Available at http://ideas.repec.org/p/fpr/polbrf/1a.html.

Yu, T.-H. E., D. A. Bessler and S. Fuller (2006) *Cointegration and Causality Analysis of World Vegetable Oil and Crude Oil Prices*, American Agricultural Economics Association (New Name 2008: Agricultural and Applied Economics Association). Available at http://ideas.repec.org/p/ags/aaea06/21439.html.

Zagaglia, P. (2010). 'Macroeconomic factors and oil futures prices: A data-rich model', *Energy Economics*, vol. **32**(**2**), pp. 409-417.

Zhang, X., L. Yu and S. Y. Wang (2009). 'The Impact of Financial Crisis of 2007-2008 on Crude Oil Price', *Computational Science - Iccs 2009*, vol. **5545**, pp. 643-652

920.

Zhang, Y. J. and Y. M. Wei (2010). 'The crude oil market and the gold market: Evidence for cointegration, causality and price discovery', *Resources Policy*, vol. **35**(**3**), pp. 168-177.

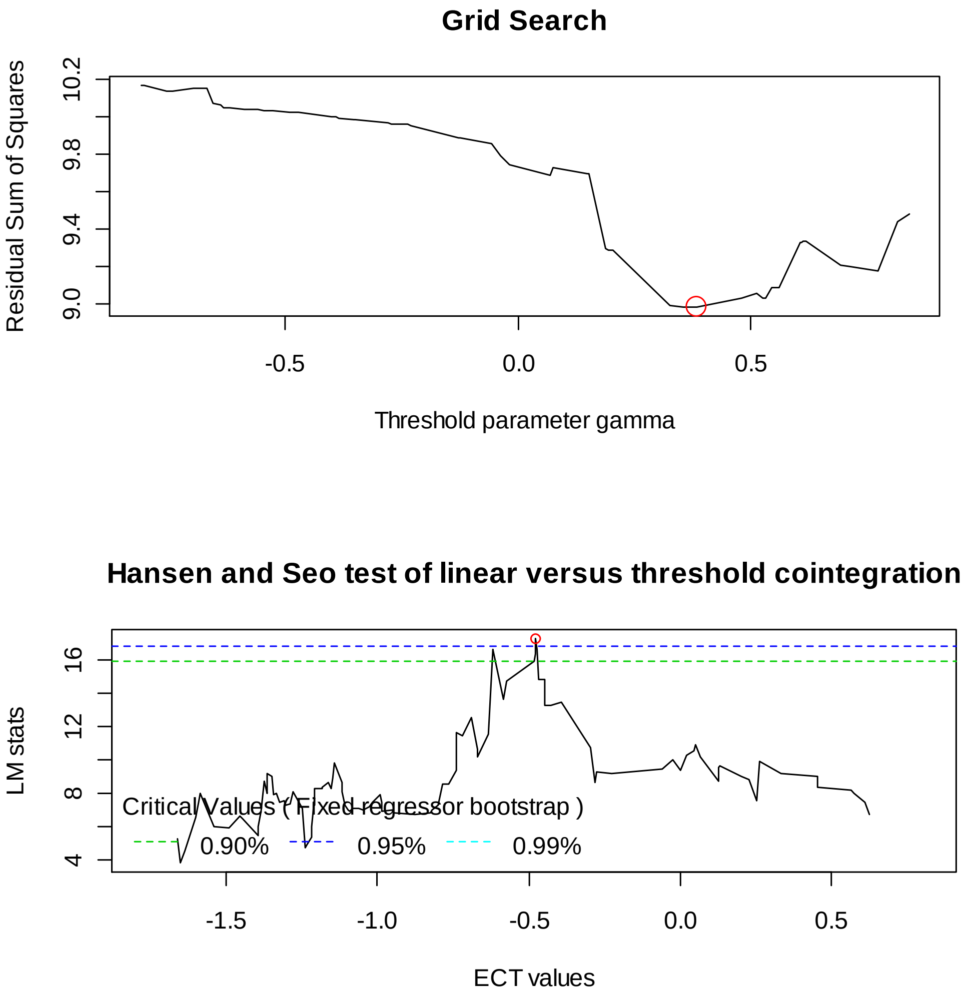

Figure 11: Testing for TVECM (Antonio *et al.*, 2009; Hansen and Seo, 2002)

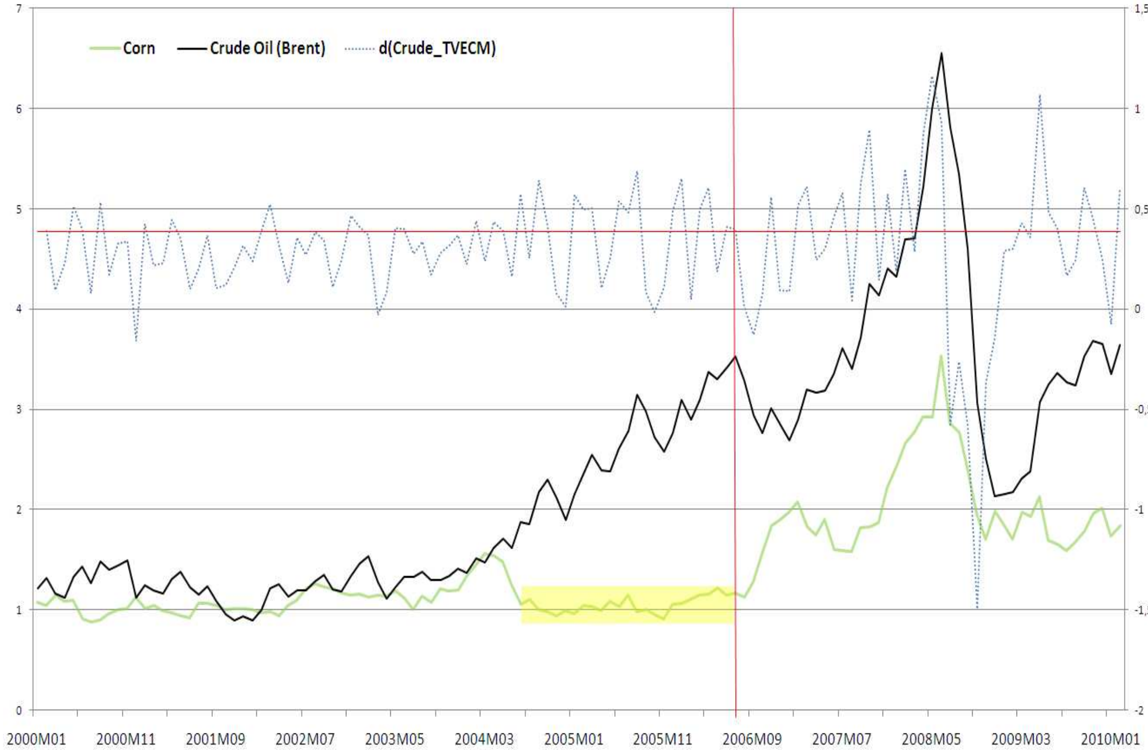

Figure 12: Interpretation of threshold cointegration for the bivariate system of crude oil – corn

Table 2: Estimates of long run & the speed of the adjustment from ECM

Models	1989 - 2010 Period Regressors	Parameter estimates	t-test	1993-2001 Period Regressors	Parameter estimates	t-test	2002-2010 Period Regressors	Parameter estimates	t-test
Crude oil-Cocoa¢	β	-0.51**	-6.08	β	-1.92**	6.81	β	1.86**	-4.67
	ECT_{t-1}	-0.11**	-3.94	ECT_{t-1}	-0.11*	1.72	ECT_{t-1}	-0.06**	-3.80
Crude oil-Rough rice	β	-	-	β	-	-	β	-	-
	ECT_{t-1}	-	-	ECT_{t-1}	-	-	ECT_{t-1}	-	-
Crude oil-Soybeans	β	-	-	β	1.72**	6.30	β	-	-
	ECT_{t-1}	-	-	ECT_{t-1}	-0.18**	-4.99	ECT_{t-1}	-	-
Crude oil-Soybean oil	β	-	-	β	-0.49***	-4.14	β	-	-
	ECT_{t-1}	-	-	ECT_{t-1}	-0.30***	-3.70	ECT_{t-1}	-	-
Crude oil-Wheat¢	β	-0.30**	-395	β	3.21**	3.66	β	1.15**	2.61
	ECT_{t-1}	-0.11**	-3.61	ECT_{t-1}	-0.06**	-3.27	ECT_{t-1}	-0.15**	-3.62
Crude oil-Sugar	β	-	-	β	2.25**	4.52	β	-	-
	ECT_{t-1}	-	-	ECT_{t-1}	-0.11**	-3.94	ECT_{t-1}	-	-
Crude oil-Corn	β	-0.25**	-3.45	β	3.14**	4.32	β	-	-
	ECT_{t-1}	-0.10**	-3.58	ECT_{t-1}	-0.07**	-3.92	ECT_{t-1}	-	-
Crude oil-Coffee	β	-	-	β	-	-	β	0.30**	-8.20
	ECT_{t-1}	-	-	ECT_{t-1}	-	-	ECT_{t-1}	-0.48**	3.28
Crude oil-Gold¢	β	-1.88**	-5.69	β	1.63**	4.97	β	-0.96**	-5.72
	ECT_{t-1}	-0.02**	-3.35	ECT_{t-1}	-0.14**	-4.49	ECT_{t-1}	-0.11**	-3.66

** indicates the significance level at 5%

Table 3: Long run causality from Johansen VECM (weak exogeneity test)

Models	1993-2001 Period Causality test A	B	Causality Decision	2002-2010 Period Causality test A	B	Causality Decision
Cocoa-Crude Oil¢	3.35* (0.07)	9.74*** (0.00)	**Cocoa → Crude Oil**	14.75*** (0.00)	0.19 (0.66)	**Crude Oil→ Cocoa**
Rough rice-Crude Oil	-	-	-	-	-	-
Soybeans-Crude Oil	1.58 (0.21)	28.85*** (0.00)	**Soybeans → Crude Oil**	-	-	-
Soybean Oil-Crude Oil¢	13.56*** (0.00)	3.10* (0.08)	**Crude Oil ↔ Soybean Oil**	-	-	-
Wheat-Crude Oil¢	0.92 (0.34)	11.62*** (0.00)	**Wheat → Crude Oil**	2.51 (0.11)	13.65*** (0.00)	**Wheat → Crude Oil**
Corn-Crude Oil	0.24 (0.63)	16.37*** (0.00)	**Corn → Crude Oil**	-	-	-
Coffee-Crude Oil	-	-	-	0.64 (0.42)	7.78** (0.01)	**Coffee → Crude Oil**
Sugar-Crude Oil	0.00 (0.95)	11.79*** (0.00)	**Sugar → Crude Oil**	-	-	-
Gold-Crude Oil¢	0.35 (0.56)	21.97*** (0.00)	**Gold → Crude Oil**	13.71*** (0.00)	1.03 (0.31)	**Crude Oil → Gold**

A indicates $H_0: \alpha_1 = 0$ vs $H_1: \alpha_1 \neq 0$
B indicates $H_0: \alpha_2 = 0$ vs $H_1: \alpha_2 \neq 0$
Parentheses indicate the probability level
¢ indicates that the results derived from model 3 and else is model 2
→ indicates unidirectional causality
↔ indicates bi-directional causality

Table 4: Test of no cointegration versus threshold cointegration (Antonio *et al.*, 2009; Seo, 2006) - *1000 bootstrap*

Crude Oil -	Test Statistic	P-value	Threshold parameter (L)	Threshold parameter (H)
Corn	29.21** (26.61)	0.02	0.72	1.94
Soyabeans	19.89 (21.81)	0.12	0.55	1.68
Soyabean Oil	30.73 (35.83)	0.2	0.97	1.75

Critical values (95%) are shown in parentheses under the respective test statistic