Do Spot Prices Move towards Futures Prices? A Study on Crude Oil Market

Mihaela Nicolau[1]

Abstract: The importance of studying the futures markets and the relationship between spot and futures prices is given by the possibility that futures contracts offer in order to reduce particular risks. The financial theory presents the relationships between spot and futures prices in the framework of both the non-arbitrage theory and the asset pricing theory, but none of themoffer information about the direction of causality between spot and futures prices. This paper attempts to analyse the dynamic relationship between spot and futures prices of the crude oil, a very important commodity. The empirical analysis is focused to examinethe causal dynamics between spot and futures prices in crude oil market; the results confirm that the prices of one and two maturity futures predict spot prices. Conversely, this is not true for longer maturity futures contracts.

Keywords: spot and futures prices relationship; futures markets; WTI; Granger causality

JEL Classification: C58; G13

1 Introduction

The importance of studying the futures markets and the relationship between spot and futures prices is given, mainly, by the possibility that futures contracts offer to reduce particular risks, but also due to its price discovery role.

The risk transfer role of the futures contract results from the fact that on the futures markets risks are reallocated between hedgers and speculators.

On the other hand, futures contract prices, especially in commodity markets, transmit information to all economic agents. Thus, producers may base their supply decisions on the futures prices, while physical traders might use futures prices as a reference to price their commodities. Considering these, there may be assumed that futures markets dominate spot commodity markets, a problem that has been often analysed during the last decades. To be mentioned here the study of Danthine (1978) who shows that the informative role of futures markets could also have a stabilising effect on spot prices, but also the studies of Turnovsky (1983), Kawai (1983), Chari for example.

The explicit linkage between spot and futures prices is presented in financial theory

[1]Senior Lecturer, PhD, Faculty of Economic Sciences, Danubius University of Galati, Romania, Address: 3 Galati Blvd, Galati, Romania, Tel.: +40372 361 102, fax: +40372 361 290, Corresponding Author: m.nicolau@univ-danubius.ro.

by both the non-arbitrage theory and the asset pricing theory.

According to the former approach, to avoid the arbitrage opportunities the futures price of a commoditymust hold the following condition:

$$F_{t,T} = (1 + r_T)P_t - (c_{t,T} - k_T), \quad (1)$$

where $F_{t,T}$ denotes the futures price of a commodity at time t for delivery at $t+T$, r_T is the risk-free T-period interest rate, $P_t$represents the spot price at time t, $c_{t,T}$ is the capitalized flow of marginal convenience yield, and k_T denotes the per-unit cost of physical storage.

The asset pricing theory establishes a relationship between the futures price and the expected future spot price, $E_t(P_{t+T})$. According to this theory, the futures price is a biased estimate of the future spot price, and is given by the equation (2).

$$F_{t,T} = E_t(P_{t+T}) - (R_T - r_T)P_t \quad (2)$$

$R_T$denotes the risk-adjusted discount rate, and $(R_T - r_T)$ represents the risk premium.

The above equations denote there is an explicit relationship between spot, futures and future spot prices, but no information about the direction of causality between spot and futures prices is offered. This lacking is covered by the financial literature (e.g. the studies of Garbade& Silver (1983), Hernandez & Torero (2010) etc.).

This study attempts to analyse the dynamic relationship between spot and futures prices of the crude oil, a very important commodity. The empirical part of the study is focused to examine causal links between spot and futures prices in crude oil market, by using recent price data. The Granger causality tests to determine the direction of information flows between spot and futures oil markets is performed.

A literature review regarding the argument is presenting in the Section 2 of the study; Section 3 illustrates characteristics of the data and the applied methodology, while the results and the conclusions are compressing in Section 4.

2. Literature Review

There are a very large number of studies with various approaches regarding the interaction between spot and futures prices of assets as commodities, agricultural products or financial instruments. Researches regarding the interactions between crude oil's spot and futures prices are numerous. Many of them analyse the price of the West Texas Intermediate (WTI), while others study the price of Brent and Dubai crude oil[1].

[1]The West Texas Intermediate, known also as *Texas Light Sweet*, is a type of crude oil. Its price is often used as benchmark. This type of crude oil represents the underline asset of the futures contracts

Lean et al. (2010) make an analysis regarding the market efficiency of oil spot and futures, by using two approaches, respectively mean-variance and stochastic dominance. Thiscontribution uses WTI crude oil data from 1989 to 2008 and the results show no evidence of any MV and SD relationships between oil spot and futures indices. Thus, the authors prove that there is no arbitrage opportunity between oil spot and oil futures markets, spot and futures do not nominate one another, investors are indifferent to investing spot or futures, and the spot and futures oil markets are efficient and rational.

Bekiros & Diks (2008) made a previous study about the relationship between crude oil spot and futures prices. They investigate the linear and nonlinear causal linkages between daily spot and futures prices for maturities of one, two, three and four months of WTI crude oil over two periods: October 1991 – October 1999 and November 1999 – October 2007. They apply the conventional linear Granger causality test and a new nonparametric test for nonlinear causality after controlling for cointegration. They test for causality while correcting for the effects of the other variables. Bekiros & Diks (2008) also examine the nonlinear causal relationships of VECM filtered residuals in order to check if any of the observed causality is strictly nonlinear in nature. The hypothesis of nonlinear non-causality is investigating after controlling for conditional heteroskedasticity in the data using a GARCH-BEKK model. The results show that the linear causal relationships disappear after VECM cointegration filtering, while nonlinear causal linkages in some cases persist after GARCH filtering in both periods which indicates that spot and futures returns may exhibit asymmetric GARCH effects and statistically significant higher order conditional moments. As the authors underline, the results imply that if nonlinear effects are accounted for, neither markets leads or lags the other consistently. More recent studies regarding oil spot and futures prices that use GARCH models as methodology are those by Arouri et al (2012), Chang et al (2011), Bu (2011). Other significant that must be mentioned are those of Liu & Wan (2011), Wang et al (2011), Lee & Zeng (2011), Lei & Yong (2011), Kaufmann& Ullman (2009).

The literature presents also researches that analyse the behaviour of crude oil spot and futures prices around OPEC and U. S. Strategic Petroleum Reserve (SPR) announcements. An example is the study realized by Demirer and Kutan (2010) that examine the abnormal returns in crude oil spot and futures markets around OPEC conference and SPR announcement dates between 1983 and 2008. Their findings regarding OPEC announcements indicate that only OPEC production cut announcements yield a statistically significant impact, with the impact diminishing for longer maturities. Regarding the SPR announcements, they find that the market

traded on Chicago Mercantile Exchange. The Brent oil represents the benchmark for the European crude oil, and the Dubai Crude, known also as *Fateh*, is the benchmark for the Asian oil market; the futures contracts of Dubai crude are limited to one or two month maturity.

reacts efficiently to these announcements providing support for the use of the strategic reserves as a tool to stabilize the oil market.

3. Data and Methodology

The aim of this section is to empirically verify both the interactions between crude oil spot and futures prices, and if the previous results of financial literature according to which futures price predicts spot price applies. Therefore, the markets involved in the empirical part are crud oil spot market and crude oil futures market.

The analysis is made in terms of daily data representing WTI spot and futures prices from New York Mercantile Exchange. The sample period of the empirical analysis ranges from 01/01/1999 to 24/07/2012 (3534 observations), representing five time series are used, respectivily: the WTI spot price (S_O), the WTI futures contract price with one (F1_O), two (F2_O), three (F3_O) and four month maturity (F4_O). The futures prices are the official daily closing prices at 2:30 p. m. from the trading floor of the New York Mercantile Exchange (NYMEX) for a specific delivery month. For crude oil, each contract expires on the third business day prior to the 25th calendar day of the month preceding the delivery month. The source of the data is Energy Information Administration (EIA).

The method applied in the analysis allows us to examin the dynamic relationships between spot and futures prices by using a battery of VAR and VECM models through which the analysis of Granger causality is realised.

Figures 1-4 show the evolution of spot and futures prices for the crude oil commodity during the entire sample period, in real terms.

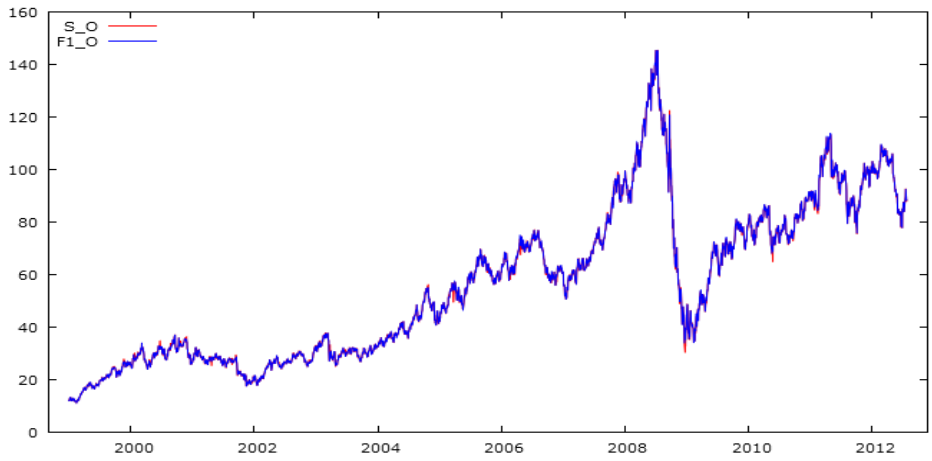

Figure 1. Crude oil: Daily spot (S_O) and futures with 1 month maturity(F1_O) crude oil prices

Two patterns emerge from the above nominated graphics. First, all the 4 figures reveal a strong positive correlation between spot and futures prices. More precisely, the time series appear to be cointegrated. The second pattern that emerges is the presence of both contago and backwardation conditions on futures markets, but with differences between the four type of futures contracts.

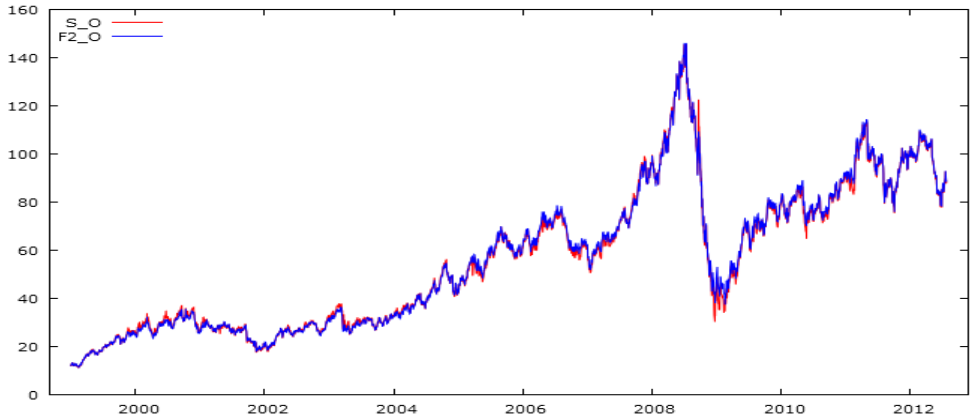

Figure 2. Crude oil: Daily spot (S_O) and futures with 2 month maturity (F2_O) crude oil prices

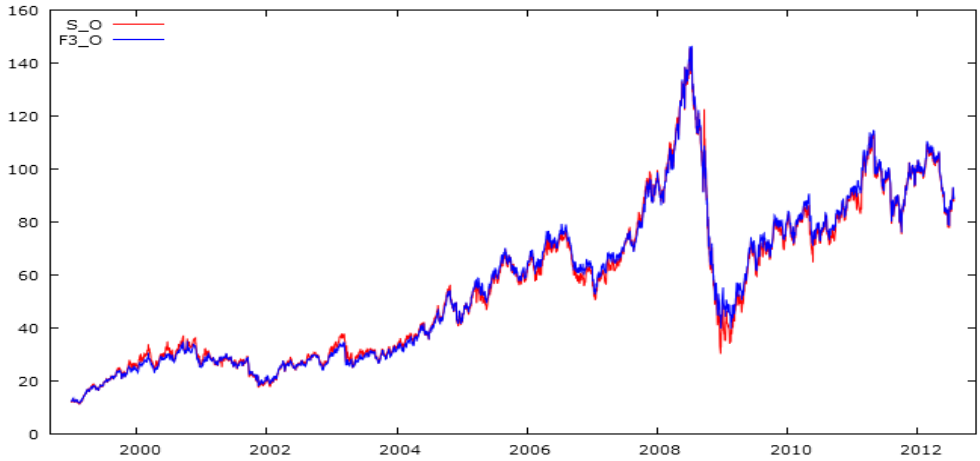

Figure 3. Crude oil: Daily spot (S_O) and futures with 3 month maturity (F3_O) crude oil prices

Thus, the market of the futures with 1 month maturity (F1_O), exhibit strong contago condition during the entire sample period, with the exception of the year 2000, when condition of backwardation was met (Figure 1).

The same characteristics result from the Figure 2, where the spot and the futures with 2 month maturity prices are represented, but in this case the condition of backwardation is met also during the end of 2002 and entire 2003 years. Figures 3 and 4, that illustrate evolution of spot and futures with 3 and 4 month maturity prices show a continue backwardation starting the end of 1999 year until the end of 2004 year.

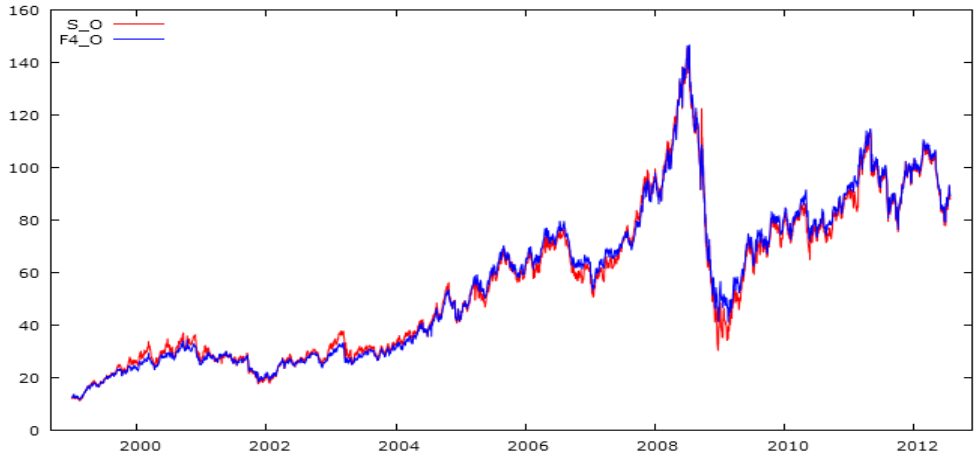

Figure 4. Crude oil: Daily spot (S_O) and futures with 4 month maturity (F4_O) crude oil prices

A contago position is normal for the crude oil commodity futures market given the fact that crude oil is a non-perishable commodity and it has a cost-of-carry. In the case of our sample period, the contago is met for all 4 futures contracts included in the analysis starting 2005 year.

4.1. Causality Tests

In order to analyse the dynamic relationship between spot and futures prices, Granger causality tests were conducted. These tests allow us to examine if changes in the price of futures lead changes in spot prices, if changes in spot prices lead changes in futures prices, or both. The analysis is conducted on spot and futures prices for different maturities taking into consideration the cointegration relationship among them.

The Granger causality examines if the past values of a variable could explain its current values or the past values of another variable. In this paper, the presence of cointegration leads to the estimation of VECM model for which the standard methods to evaluate the Granger causality does not apply. In this context, the Toda-Yamamoto (1995) technique is used: after evaluating the order of integration of time series, the appropriate lag length (q) for a VAR model in levels is determined.

Subsequently, the Johansen (1996) procedure is used to estimate the rank of cointegration: given that all the models of interest are bivariate VARs, if cointegration exists, the rank has to be one.[1] Toda and Yamamoto (1995) claim that the Granger causality test could be carried out by using a standard Wald test applied to a VAR model for prices (nonstationay) with q+1 lags. Specifically, the null hypothesis imposes a zero restriction on the first q lags for both the variables involved.

Following the Hannan-Quinn information criterion, the number of lags to be included in the empirical analysis is 4, while the Johansen test with restricted constant suggests that the rank of cointegration is always one, hence a VAR(5) model in levels is estimated for carrying out the Granger causality test.[2] The results of Johansen test are presented in the upper side of Table 1, while the results of related test about the null hypothesis under which the vector of cointegration is (1, -1) and the cointegrated vectors with standard errors are illustrated by thelower part of Table 1.

Table 1. Tests results

Johansen test			
Rank	Eigenvalue	Trace test	Lmax test
Variables S_O, F1_O			
0	0.15632	607.29	600.72
		(0.0000)	(0.0000)
1	0.0018551	6.5621	6.5621
		(0.1563)	(0.1561)
Variables S_O, F2_O			
0	0.026046	99.917	93.265
		(0.0000)	(0.0000)
1	0.0018804	6.6517	6.6517
		(0.1505)	(0.1503)
Variables S_O, F3_O			
0	0.015652	62.392	55.753
		(0.0000)	(0.0000)
1	0.0018769	6.6391	6.6391
		(0.1513)	(0.1511)
Variables S_O, F4_O			
0	0.012564	51.309	44.682
		(0.0000)	(0.0000)
1	0.0018735	16.6270	6.6270
		(0.1521)	(0.1519)

[1]If the rank of cointegration is zero, the model is a bivariate nonstationary VAR, while a full cointegration rank indicates a bivariate stationary VAR.

[2] All the results are available upon request from the author.

H_0: Vector of cointegration is (1, -1)				
Variables	LR	p-value	β_{S_O}	β_{F_O}
S_O, F1_O	9.57598	0.00197139	1.0000	-0.99828
			(0.00000)	(0.000549)
S_O, F2_O	8.12347	0.00436958	1.0000	-0.98618
			(0.00000)	(0.0045559)
S_O, F3_O	8.2783	0.00401217	1. 0000	-0. 97150
			(0.00000)	(0.0089251)
S_O, F4_O	9.09685	0.0025605	1. 0000	-0. 95675
			(0.00000)	(0.012480)

5. Results and Conclusions

The Granger causality test results for spot and futures returns, for all four type of futures contracts and for the whole sample period are presented in Table 3. The upper section of the table reports the F-statistic for the null hypothesis that futures returns does not Granger-cause the spot returns; the lower section reports F-statistic for the null hypothesis that the spot returns does not Granger-cause the futures returns.

Table 3. Granger causality tests of daily returns in crude oil spot and futures markets, 01/01/1999 – 24/07/2012

H_0: Futures returns does not Granger-cause spot returns		
Variables	F-statistic	p-values
S_O, F1_O	29.5092	0.000000
S_O, F2_O	2.30588	0.055965
S_O, F3_O	0.775356	0.541078
S_O, F4_O	0.532331	0.711994
H_0: Spot returns does not Granger-cause futures returns		
Variables	F-statistic	p-values
F1_O, S_O	3.20521	0.012289
F2_O, S_O	5.92799	0.000000
F3_O, S_O	5.08694	0.000000
F4_O, S_O	6.44556	0.000000

Note: H_0= null hypothesis, S_O = WTI spot price, F1_O = WTI futures with 1 month maturity price; F2_O = WTI futures with 2 months maturity price; F3_O = WTI futures

with 3 months maturity price; F4_O = WTI futures with 4 month maturity price.

As can be seen, the null hypothesis that the returns in WTI futures markets does not Granger-cause the returns in WTI spot market is fully rejected only in the case of WTI futures with 1 month maturity, while in the case of WTI futures with 2 months maturity, is accepted at the standard critical value of 5%. The same is for the futures with maturity longer than 2 months. In other words, returns of futures contracts with shorter delivery dates influence the returns in WTI spot prices.

On the other hand, the bottom side of the table illustrates that the null hypothesis that the returns in WTI spot markets does not Granger-cause the returns in WTI futures market is rejected for all four types of WTI futures contracts.

In conclusion, the financial literature according to which futures prices predicts spot price does not apply for all types of WTI future contracts. Only the futures with one monthmaturity could be considered as a driverfor the WTI spot markets but, at the same time, the WTI spot market influence the WTI futures with 1 month maturity.

6. References

Arouri, M. E. H. & Lahiani, A. & Lévy, A. & Nguyen, D. K. (2012). Forecasting the conditional volatility of oil spot and futures prices with structural breaks and long-memory models. *Energy Economics*, Vol. 34, No. 1, pp. 283-293.

Bekiros, S. D., &Diks, G. H. (2008). The relationship between crude oil spot and futures prices: Cointegration, linear and nonlinear causality. *Energy Economics*, Vol. 30, No. 5, 2673-2685.

Bu, H. (2011). Price Dynamics and Spaculators in Crude Oil Futures Market. *Systems Engineering Procedia*, Vol. 2, pp. 114-121.

Chang, C.-L.; McAleer, M. &Tansuchat, R. (2011). Crude oil hedging strategies using dybamic multivariate GARCH. *Energy Economics*, Vol. 33, No. 5, pp. 912-923.

Danthine, J. P. (1978). Information, futures prices, and stabilizing speculation. *Journal of Econmic Theory*, Vol. 51, No. 1, pp. 79-98.

Demirer, R. & Kutan, A. M. (2010). The behavior of crude oil spot and futures prices around OPEC and SPR announcements: An event study perspective. *Energy Economics*, Vol. 32, No. 6, 1467-1476.

Garbade, K. & Silver, W. (1983). Price movements and price discovery in futures and cash markets. *Review of Economics and Statistics*, Vol. 65, No. 2, pp. 289-297.

Hernandez, M. & Torero, M. (2010). *Examining the Dynamic Relationship between Spot and Future Prices of Agricultural Commodities*. Washington, D.C.: International Food Policy Research Institute.

Johansen, S. (1996). *Likelihood-Based Inference in Cointegrated Autoregressive Model*. Oxford: Oxford University Press.

Kaufmann, R. K., Ullman, B. (2009). Oil prices, speculation, and fundamentals: Interpreting causal relations among spot and futures prices. *Energy Economics*, Vol. 31, No. 4, pp. 550-558.

Kawai, M. (1983). Price volatility of storable commodities under rational expectations in spot and futures markets. *International Economic Review*, Vol. 24, No. 2, pp. 435-459.

Lean, H. H. & McAleer, W. & Wong, W-K. (2008). Markey efficiency of oil spot and futures: A mean-variance and stochastic dominance approach. *Energy Economics*, Vol. 52, No. 5, pp. 979-986.

Lee, C. -C., Zeng, J. -H. (2011). Revisiting the relationship between spot and futures oil prices: Evidence from quantile conitegrating regression. *Energy Economics*, Vol. 33, No. 5, pp. 924-935.

Liu, L. & Wan, J. (2011). A study of correlations between crude oil spot and futures markets: A rolling sample test. *Physica A*, Vol. 390, No. 21-22, pp. 3754-3766.

Toda, H. Y. &Yamamoto, T. (1995). Statistical inferences in vector autoregressions with possibly integrated processes. *Journal of Econometrics*, Vol. 66, pp. 225-50.

Turnovsky, S. (1983). The determination of spot and futures prices with storable commodities. *Econometrica*, Vol. 51, No. 5, pp. 1363-1387.

Wang, Y. & Wei, Y. & Wu, C. (2011). Detrended fluctuation analysis on spot and futures markets of West Texas Intermediate crude oil. *Physica A*, Vol. 390, No. 5, pp. 864-875.