Petroleum-Gas University of Ploiesti BULLETIN	Vol. LXII No. 4/2010	75 - 82	Economic Sciences Series

Testing the Cointegration of Oil Prices and Energy Sector Equity Indices

Alecsandru-Oancia Constantin, Bogdan Cernat-Gruici

Academy of Economic Studies Bucharest, Faculty of Commerce, 41 Dacia Blvd., Bucharest, Romania
e-mail: constantinlauragabriela@gmail.com

Abstract

The aim of the present paper is to study the relationship between international oil prices and international energy sector in the context of the current economic crisis. The research methodology consists in co-integration tests performed on daily data frequency for two of the most important spot oil prices used as a benchmark in oil pricing, mainly the West Texas Intermediate (WTI) and the Europe Brent and for the All Country World Energy Index, an MSCI index, that tracks the performance of the energy sector.

Key words: *spot oil price, international capital markets, cointegration*

JEL Classification: *G01, G15*

Introduction

The purpose of our paper is to capture the relationship between international oil markets and the international energy sector and to focus on the present economic crisis period by employing the cointegration technique.

With regard to the scientific literature concerning the subject of our analysis, Sauter and Awerbuch (2002)[1] provide a comprehensive review of the studies approaching oil price movements and their effect on economic and financial performance in IEA (International Energy Agency) countries, and tackle the effects of the oil price changes on the stock markets. The authors mention that the first study to analyze whether the reaction of international stock markets to oil shocks can be justified by current and future changes in real cash flows and/or changes in expected returns is that of Jones and Kaul (1996) that examine four markets: US, Canada, UK and Japan[2]. Papapetrou (2001), by focusing on the Greek market, uses a vector-autoregressive method in investigating the dynamic relationship between oil prices, real stock prices, interest rates, real economic activity and employment. The author concludes that impulse response functions show that oil prices are important in explaining stock price movements, the results suggesting that a positive oil price shock depresses real stock returns and that lasts for

---

[1] Sauter, R., Awerbuch, S., *Oil price Volatility and Economic Activity: A Survey and Literature Review*, Research Paper, Paris: IEA, August, 2003, Exposure Draft: 25-Sep-02.

[2] Jones, C.M., Kaul, G., Oil and the Stock Markets, *The Journal of Finance*, Vol LI, No. 2, pp. 463-91, 1996, pp. 463-91.

approximately four months[3]. Lake and Katrakilidis (2009)[4] investigated the impact of oil price returns and oil price volatility on the Greek, the US, the UK and the German stock markets, using monthly data that covered the September 1999 – March 2007 period. The study concludes that both the Greek and the US stock market index returns are sensitive to the oil price returns changes. However, the German and the UK stock market returns are not influenced by the oil price returns movements

Before the 1980s many economists used linear regressions on (de-trended) non-stationary time series data, which Clive Granger and others showed to be a dangerous approach that could produce spurious correlation. His 1987 paper with Robert Engle formalized the cointegrating vector approach. Cointegration is an econometric property of time series variables. If two or more series are individually integrated but some linear combination of them has a lower order of integration then the series are said to be co-integrated. A common case is where the individual series are first-order integrated – I(1) but some (cointegrating) vector of coefficients exist to form a stationary linear combination of them. It is often said that cointegration is a means for correctly testing hypotheses concerning the relationship between two variables having unit roots (i.e. integrated of at least order one). A series is said to be "integrated of order “t” if one can obtain a stationary series by “differencing” the series t times. The usual procedure for testing hypotheses concerning the relationship between non-stationary variables was to run Ordinary Least Squares (OLS) regressions on data which had initially been differentiated.

In statistics, the Johansen test is a procedure for testing cointegration of several time series. This test does not require all variables to be in the same order of integration, and hence this test is much more convenient than the Engle–Granger test for unit roots which is based on the Dickey–Fuller (or the augmented) test. There are two types Johansen[5] test, either with trace or with eigenvalue, and the inferences might be a little bit different. The null for trace test is the number of cointegration vector $r \leq ?$, for eigenvalue test is $r = ?$. Just like a unit root test, there can be constant term, trend term, or both, or neither in the model. For a general VAR(p) model :

$$X_t = \mu + \Phi D_t + \Pi_p X_{t-p} + \ldots + \Pi_1 X_{t-1} + e_t, \qquad t=1,\ldots,T$$

There are two possible specifications for error correction: that is, two VECM (vector error correction models):

The longrun VECM:

$$\Delta X_t = \mu + \Phi D_t + \Pi X_{t-p} + \Gamma_{p-1}\Delta X_{t-p+1} + \Gamma_1 \Delta X_{t-1} + \ldots + \varepsilon_t, \qquad t = 1,\ldots,T$$

where:

$$\Gamma_i = \Pi_1 + \ldots + \Pi_i - I, \qquad i = 1, \quad ,p\text{-}1$$

The transitory VECM:

$$\Delta X_t = \mu + \Phi D_t - \Gamma_{p-1}\Delta X_{t-p+1} - \ldots - \Gamma_1 \Delta X_{t-1} + \Pi X_{t-1} + \varepsilon_t, \qquad t = 1,\ldots,T$$

where:

$$\Gamma_i = (\Pi_{i+1} + \ldots + \Pi_p) \qquad i = 1, \quad ,p\text{-}1$$

In both VECM,

$$\Pi = \Pi_1 + \ldots + \Pi_p - I$$

---

[3] Papapetrou, E., Oil price shocks, stock market, economic activity and employment in Greece, *Energy Economics*, vol. 23, issue 5, 2001, pp. 511-532

[4] Lake, A.E., Katrakilidis, C., The Effects of the Increasing Oil Price Returns and its Volatility on Four Emerged Stock Markets, *European Research Studies Journal*, Volume XII, Issue (1), 2009, pp. 149-161.

[5] Quantitative Micro Software, LLC, *EViews 5 User's Guide*, Printed in the USA, 1994–2004.

Inferences are drawn on Π, and they will be the same, which is also the case for the explanatory power.

Testing Time Series Cointegration

Data description. We considered for the analysis daily time series for the period January 3, 2008 to March 30, 2010, on the one hand, the two most important spot oil prices, on the other hand, the international energy index calculated by MSCI Barra. Oil market data was obtained from the Energy Information Administration - EIA (Agency for Statistics and analytical analysis of the U.S. Department of Energy) and the data for the MSCI index from Thomson Reuters (financial information group, the most important information source for companies and specialists). Thus, the oil market was represented by London Brent Crude Oil spot prices, called from now on BRENT and Cushing OK WTI, named WTI. The MSCI index selected in analysis is the All Country World Energy Index, named ACWIEN or MSCI from now on.

Testing the stationarity of the time series. Cointegration, if it exists, one should presume that the series have a unit root.

Therefore, as an initial stage of the cointegration analysis, all the time series were tested to identify whether they are stationary (unit root tests). In this sense, the graphs were made for each time series (for both the oil market and for capital markets previously presented). In Figure 1 we display the All Country World Energy Index.

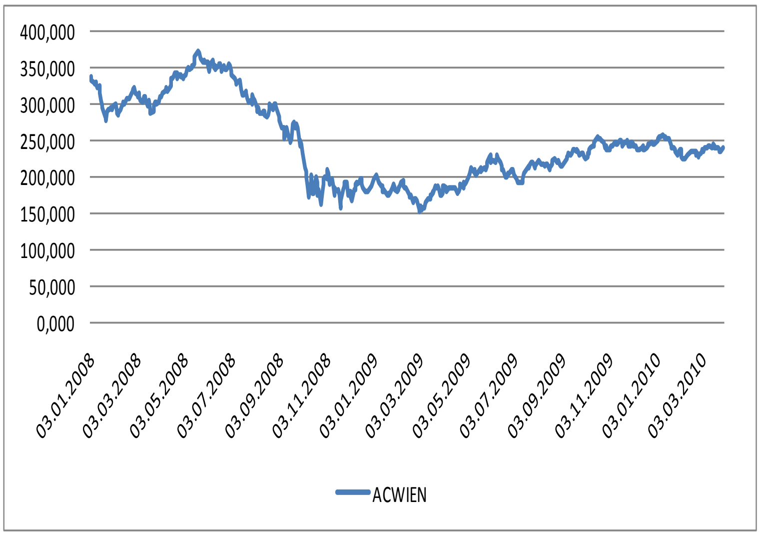

Fig. 1. All Country World Energy Index

Applying the ADF test to test stationarity. In order to verify the stationarity of the time series the Augmented Dickey-Fuller test was applied. Given the sample probability value (PValue) we cannot reject the null hypothesis for the time series. Therefore, it can be concluded that time series studied are non-stationary (Table 1).

Table 1. Augmented Dickey-Fuller stationarity test for prices

Null hypothesis	t-Statistic	Prob.
BRENT has a unit root	-0.852665	0.9590
WTI has a unit root	-1.045257	0.9355
ACWIEN has a unit root	-1.312829	0.8836

Furthermore, all the time series were transformed by calculating the time series log returns (original time series were logged and then the first difference has been applied). Both for the logarithmic series and return series the Augmented Dickey-Fuller test was conducted. The results of the ADF test are displayed in Table 2 and Table 3.

As it is shown, following the changes made, we can assume the logarithmic time series are non-stationary (Prob.> 5% cannot reject the null hypothesis of non stationarity, Table 2) but their first difference is stationary (Prob. = 0, can reject the null hypothesis of non stationarity, Table 3).

Table 2. Augmented Dickey-Fuller stationarity test on logarithmic series

Null hypothesis	t-Statistic	Prob.
BRENT_LOG has a unit root	-0.949399	0.9483
WTI_LOG has a unit root	-1.076681	0.9307
ACWIEN_LOG has a unit root	-1.262511	0.8955

Table 3. Augmented Dickey-Fuller stationarity test on returns

Null hypothesis	t-Statistic	Prob.
BRENT_R has a unit root	-23.43299	0.0000
WTI_R has a unit root	-23.57548	0.0000
ACWIEN_R has a unit root	-19.27053	0.0000

The previous analysis revealed that the *logarithmic series of the BRENT, WTI and ACWIEN are I(1) – first-order integrated*. Given that the goal of the cointegration test is to determine whether non-stationary series in a group are or not cointegrated, we proceeded our Eviews study by employing the Johansen test. Given these issues, the analysis initially focused on the test for cointegration for the associated I(1) variables (MSCI_LOG and WTI_LOG and respectively MSCI_LOG and BRENT_LOG).

Johansen cointegration test. We considered in the analysis the optimal length as determined for each pair of price-index, using different criteria, such as likelihood-ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC) and Hannan-Quinn Information Criterion (HQ).

In order to determine the number of cointegrating vectors, the Johansen method provides two different likelihood ratio tests, the trace test and the maximum eigenvalue test, the results being displayed in the following tables (Table 4, Brent spot price – ACWIEN and Table 5, WTI spot price – ACWIEN).

As one can notice, the trace and maximum eigenvalue cointegration test results presented in Table 4 fail to reject the null hypothesis of no cointegration between the Brent oil price and the selected energy index – ACWIEN, at the 5 percent level of significance, for the period under consideration.

By examining Table 5, one fails to reject the null hypothesis of no cointegration, at the 5 percent level of significance, between the WTI oil price and the selected energy index – ACWIEN, for the period under consideration.

Therefore, by examining both Table 4 and Table 5, one can assert that the empirical findings support the presence of one cointegrating vector for each of the two pairs of analyzed time series.

Table 4. Johansen cointegration test BRENT_LOG - ACWIEN_LOG
Optimal lag no = 7 sites

Hypothesized No. of CE(s)	Eigenvalue	*Trace Statistic*	Prob
None	0.034189	22.06560	0.0044
At most 1	0.004958	2.758578	0.0967
Trace test indicates 1 cointegrating eqn(s) at the 0.05 level			

Hypothesized No. of CE(s)	Eigenvalue	*Max-Eigen Statistic*	Prob
None	0.034189	19.30702	0.0073
At most 1	0.004958	2.758578	0.0967
Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level			

Table 5. Johansen cointegration test WTI_LOG - ACWIEN_LOG
Optimal lag no = 6 sites

Hypothesized No. of CE(s)	Eigenvalue	*Trace Statistic*	Prob
None	0.034826	22.88595	0.0032
At most 1	0.005699	3.177585	0.0747
Trace test indicates 1 cointegrating eqn(s) at the 0.05 level			

Hypothesized No. of CE(s)	Eigenvalue	*Max-Eigen Statistic*	Prob
None	0.034826	19.70836	0.0062
At most 1	0.005699	3.177585	0.0747
Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level			

Thus we conclude that the following pairs of indices are cointegrated: BRENT_LOG - ACWIEN_LOG and WTI_LOG - ACWIEN_LOG. In other words, BRENT_LOG - ACWIEN_LOG, on the one side and WTI_LOG - ACWIEN_LOG, on the other side, are cointegrated at 95% confidence.

The following tables present the estimates of the normalized cointegrating vector(s) and their respective standard errors (in parenthesis) as to reflect how much cointegration there is for the analyzed period.

As one can notice, we displayed in Table 6 and Table 7 the relationships between the BRENT oil price and the chosen energy index and in Table 8 and Table 9 the relationship between WTI oil price and selected energy index, setting both the oil prices and the energy index as normalized variables. From Table 6 and Table 7, one can notice that there is one integrating equation, with a normalized cointegrating coefficient (*BRENT_LOG-1.677855 ACWIEN_LOG or ACWIEN_LOG-0.595999 BRENT_LOG).* Hence, an error correction model should be applied.

Table 6. Normalized cointegrating coefficients: BRENT_LOG-ACWIEN_LOG

Variable	BRENT_LOG	ACWIEN_LOG
Coefficient value	1.000000	-1.677855
Standard error		(0.12005)

Table 7. Normalized cointegrating coefficients: ACWIEN_LOG-BRENT_LOG

Variable	ACWIEN_LOG	BRENT_LOG
Coefficient value	1.000000	-0.595999
Standard error		(0.04573)

In addition, from Table 8 and Table 9, the results displayed indicate that there is a relationship between the logarithmic series of the WTI oil price and the ACWIEN, the equity energy index. Therefore, the results reveal an integrating equation, with a normalized cointegrating coefficient (*WTI_LOG*-1.677285 *ACWIEN_LOG or ACWIEN_LOG*-0.596202*WTI_LOG).* Hence, an error correction model should be applied.

Table 8. Normalized cointegrating coefficients: WTI_LOG-ACWIEN_LOG

Variable	WTI_LOG	ACWIEN_LOG
Coefficient value	1.000000	-1.677285
Standard error		(0.13747)

Table 9. Normalized cointegrating coefficients: ACWIEN_LOG-WTI_LOG

Variable	ACWIEN_LOG	WTI_LOG
Coefficient value	1.000000	-0.596202
Standard error		(0.05103)

Taking into account that the considered variables are cointegrated, we determined the error correction model that describes the short-run dynamics or adjustments of the cointegrated variables towards their equilibrium values as the vector-error correction model is employed with nonstationary series that are known to be cointegrated.

Taking into account that in Eviews, in the case of the vector error correction model, the first difference operation is done automatically, we introduced the logarithmic series. The error correction models stand for the one-period lagged cointegrating equation and the lagged first differences of the endogenous variables. In the first part of each table (Table 10-Table 13) there are displayed the estimates of the cointegrating equation, while the second part presents the estimates of the speed of adjustment (to equilibrium) coefficient with their corresponding standard errors and t-statistics.

As one can notice from Table 10 (normalized with respect to BRENT_LOG), about 4% of the disequilibrium is corrected by changes in oil price, while only 0.2% of disequilibrium is adjusted by changes of the energy index considered within the present analysis, but only the first error correction term is statistically significant (the Brent error correction term contains additional information). From Table 11 (normalized with respect to ACWIEN_LOG), one can notice that only 0.3% of disequilibrium is adjusted by changes of the energy index and about 7% of the disequilibrium is corrected by changes in oil price, only the last one being statistically significant.

Table 10. Vector Error Correction Estimates: BRENT_LOG-ACWIEN_LOG

Co-integrating Equation 1		
BRENT_LOG(-1)	1.000000	
ACWIEN_LOG(-1)	-1.677855	
Standard errors	*(0.12005)*	
t-statistic	*[-13.9763]*	
C	2.119990	
Error Correction:	**D(BRENT_LOG)**	**D(ACWIEN_LOG)**
Speed of adjustment	**-0.041658**	-0.002028
Standard errors	*(0.01087)*	*(0.00924)*
t-statistic	*[-3.83117]*	*[-0.21942]*

Table 11. Vector Error Correction Estimates: ACWIEN_LOG-BRENT_LOG

Co-integrating Equation 1	
ACWIEN_LOG(-1)	1.000000
BRENT_LOG(-1)	-0.595999
Standard errors	*(0.04573)*

t-statistic	*[-13.0340]*
C	-1.263512

Error Correction:	D(ACWIEN_LOG)	D(BRENT_LOG)
Speed of adjustment	0.003402	**0.069896**
Standard errors	*(0.01551)*	*(0.01824)*
t-statistic	*[0.21942]*	*[3.83117]*

By examining Table 12 (normalized with respect to WTI_LOG), about 4% of the disequilibrium is corrected by changes in oil price, while 0% (0.0008) of disequilibrium is adjusted by changes of the energy index ACWIEN, only the WTI error correction term being statistically significant. In addition, from the results displayed in Table 13 (normalized with respect to ACWIEN_LOG), one can notice that only 0.1% of disequilibrium is adjusted by changes of the energy index and about 6% of the disequilibrium is corrected by changes in the WTI oil price, the former error correction term being statistically insignificant, while the latter being statistically significant.

Table 12. Vector Error Correction Estimates: WTI_LOG- ACWIEN_LOG

Co-integrating Equation 1	
WTI_LOG(-1)	1.000000
ACWIEN_LOG(-1)	-1.677285
Standard errors	*(0.13747)*
t-statistic	*[-12.2013]*
C	2.111528

Error Correction:	D(WTI_LOG)	D(ACWIEN_LOG)
Speed of adjustment	**-0.037725**	0.000805
Standard errors	*(0.01093)*	*(0.00789)*
t-statistic	*[-3.45240]*	*[0.10205]*

Table 13. Vector Error Correction Estimates: ACWIEN_LOG-WTI_LOG

Co-integrating Equation 1	
ACWIEN_LOG(-1)	1.000000
WTI_LOG(-1)	-0.596202
Standard errors	*(0.05103)*
t-statistic	*[-11.6843]*
C	-1.258897

Error Correction:	D(ACWIEN_LOG)	D(WTI_LOG)
Speed of adjustment	-0.001351	**0.063275**
Standard errors	*(0.01324)*	*(0.01833)*
t-statistic	*[-0.10205]*	*[3.45240]*

Conclusions

Within the present paper we applied the Johansen test in order to study the cointegration of the most important benchmark oil spot prices (Brent and WTI) and the worldwide energy sector index measured by MSCI (ACWIEN), during the most recent economic crisis – the set of data covered two years and a quarter and we considered it as being a long period of time for a recent economic crisis. From an economic perspective, as expected, we have found a relatively strong relationship between both oil spot prices and the MSCI energy index for the studied period. More specifically, we performed unit root procedures to the time series – we tested the series in their levels, in their logarithmic values and in the first difference of their logarithmic values. The augmented Dicky-Fuller (ADF) test results revealed that both the logarithmic oil prices and the logarithmic energy sector index are first difference stationary. By applying the cointegration procedures, we have found that there is a cointegration relationship between both the Brent spot price and the AC World Energy Index and between the WTI spot price and the same energy sector index, more specifically the two pairs of oil price-energy index seem to co-move. We conclude that, even during a period of crisis, oil prices and equity markets remain important factors for world markets. As further research, we propose for study a longer period of time.

References

1. Engle, R., Granger, C., *Co-integration and error correction: Representation, estimation and testing*, Econometrica 55(2), pp. 251-276, 1987.
2. Granger, C., *Some Properties of Time Series Data and Their Use in Econometric Model Specification*, Journal of Econometrics, 16, pp. 121-130, 1981.
3. Johansen, S., *Cointegration and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models*, Econometrica, Vol.59, No.6, pp. 1551–1580, 1991.
4. Jones, C.M., Kaul, G., Oil and the Stock Markets, *The Journal of Finance*, Vol LI, No. 2, pp. 463-91, 1996.
5. Lake, A.E., Katrakilidis, C., The Effects of the Increasing Oil Price Returns and its Volatility on Four Emerged Stock Markets, *European Research Studies Journal*, Volume XII, Issue (1), 2009, pp. 149-161.
6. Papapetrou, E., Oil price shocks, stock market, economic activity and employment in Greece, *Energy Economics*, vol. 23, issue 5, 2001, pp. 511-532.
7. Quantitative Micro Software, LLC, *EViews 5 User's Guide*, Printed in the USA, 1994–2004.
8. Sauter, R., Awerbuch, S., *Oil price Volatility and Economic Activity: A Survey and Literature Review*, Research Paper, Paris: IEA, August, 2003, Exposure Draft: 25-Sep-02.
9. http://www.eia.doe.gov/
10. http://www.mscibarra.com/products/indices/international_equity_indices/definitions.html
11. http://www.mscibarra.com/products/indices/international_equity_indices/gimi/sector/MSCI_Global_Sector_Indices_factsheet.pdf

Testarea cointegrării preţurilor petrolului şi indicele de piaţă al sectorului energetic

Rezumat

Scopul articolului este de a studia relaţia dintre preţurile internaţionale ale petrolului şi sectorul energetic la nivel global în contextul crizei economice curente. Metodologia de cercetare constă în realizarea de teste de co-integrare efectuate pe serii zilnice ale celor mai importante preţuri spot ale petrolului - West Texas Intermediate (WTI) şi Europe Brent şi All Country World Energy Index utilizat pentru măsurarea performanţei sectorului energetic al pieţei de capital.