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EVALUATING THE SHORT RUN EFFECTS OF U.S. CRUDE OIL INVENTORY LEVELS ON WTI CRUDE OIL PRICE FROM 1993 - 2013

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Abstract

The focus of this research was to investigate the short-term influence of U.S. crude oil inventories on WTI crude oil prices from 1993 to 2013. This study is important for policy makers who wish to reduce the persistent and growing price volatility of crude oil and its related products as well as businesses such as airline companies who wish to make annual budgetary sales decisions. Using OLS multiple regression, cointegration, VECM and Ex-post forecast techniques; we provide evidence of an inelastic relationship in which a 1% increase in U.S. crude oil inventories is associated with 0.46% decrease in WTI crude oil prices; however this was only valid for 22% of WTI crude oil price variation. We also find that past data on U.S. crude oil inventories could be used to predict future WTI crude oil prices movement. Contrary to literature, the results of the VECM analysis indicate there is no short-run relationship between both variables over the trajectory.

Keywords: WTI Price, Crude Oil Inventories, Short Run

1. Introduction

Over the years, the prices of crude oil have indicated the presence of volatility which has been caused by various factors affecting global demand and supply, such as, unexpected weather conditions, price expectations, political crisis, economic growth, OPEC decisions amongst many others. Consequently, threat to possible shortages of crude oil has caused economies to build inventories to satisfy future demand as well as current unexpected changes in demand. Crude oil inventories can be described as a balancing scale between demand and supply. During periods in which production exceeds consumptions, inventories build up, whereas during periods in which consumption exceeds production, inventories draw down (EIA 2014). Intuitively, changes in inventory level serve as indicator of the evenness or disparity between crude oil production and demand, thus reflecting changes in the market pressure of crude oil prices in the short run (Ye *et al.*2005, p.492).

There is extensive list of literature on crude oil inventory. Alsahlawi (1998) showed that in the past, prices were more stable and changes in the demand for crude oil in winter and summer periods explained the fluctuations in inventory level. However, recent pattern of oil inventory build-up and draw-down can be explained by several factors such as political crisis, financial markets, economic growth as well as speculative actions (Beidas-Strom and Pescatori(2014); Knittel and Pindyck 2013). Consequently, these have had demonstrable effects on crude oil prices. Expectedly, this has aroused much researcher interests in this area. For example, the EIA (2014) established the basic categories of crude oil price drivers to include crude oil inventory builds among others; and there is extensive research on the effect of each of those explanatory variables put forward by the EIA in determining the price of crude oil in the global market. Such works include; Rifflart and Chevillon (2009), Biu (2011), Schmidbauer and Rosch (2012), Cashin*et al.* (2014) and Guntner (2014).The effects of changes in supply and demand of crude oil on price (Kutasovic 2012;Fattouh 2010); (the effects of economic growth on oil price (Jiménez-Rodríguez and Sánchez 2004; Husain *et al.* 2015; as well as the effects of currency exchange rates, financial market activity and geopolitics among others (EIA 2014; Rentschler, 2013). While all of these research have enabled some understanding, it appears the effects of non- weather related, inventory level swings on crude oil price has not received as much attention of energy economists. Ye *et al.*(2002, p.333) observed this too and suggested this be investigated. This establishes the premise upon which this paper founded. By critically analyzing the causes and effects of anticipated and unanticipated changes in crude oil inventory and its relative effect on crude oil prices; this paper offers explanation on the current crude oil market price volatility as it is caused by crude oil inventory level swings.

We achieve the aim of the research via an appraisal of the relationship between changes in U.S. crude oil inventory level and changes in WTI crude oil prices in the short run from 1993 till 2013. More specifically, we estimate the relative weight of U.S. crude oil inventories amongst other significant explanatory variables in explaining the movement of WTI crude oil prices overtime and investigate the future impact of changes in U.S. crude oil inventory levels on WTI crude oil prices using data from 1993 to 2013.

1.1. Research Hypotheses

For the purpose of this research the following hypotheses were pursued:

Hypothesis 1

H0 = U.S. crude oil inventories amongst other significant explanatory variables do not explain WTI crude oil price movements overtime

H1 = U.S. crude oil inventories amongst other significant explanatory variables explain WTI crude oil price movements overtime

Hypothesis 2

H0 = There is no future impact of changes in U.S. Inventory level on WTI crude oil prices using historical data from 1993 to 2013

H1 = There is future impact of changes in U.S. Inventory level on WTI crude oil prices using historical data from 1993 to 2013.

The rest of the paper is organized as follows: section 2 details the research methods, section 3 presents the empirical results and section 4 concludes.

2. Methods

2.1. Data Selection and Justification

The theory of price, asserts that the price of any commodity is determined by the interplay between forces of demand and supply, and underpins the selection of crude oil price for the research. According to Kahn, “a useful framework for studying price determination is the aggregate demand and supply model which help to determine the level of price and output (Kahn, 1984, p.17). WTI crude oil price (from January 1993 to December 2013 was sourced from EIA) and served as dependent variable while U.S. crude oil inventories data (between January 1993and December 2013from EIA) were chosen as independent variable since it was the variable of interest. All other variables served as controls. In scientific research, controls help to minimize the effects of a single independent (test) variable which may lead to alternate explanations of results, which may suffer from experimental errors and researcher's bias. All independent variables related to the U.S. This is because the research intended to even the other control variables to that of the test variable (U.S. crude oil inventories) in an attempt to reduce bias from selecting large samples such as OECD samples.

2.2. Data Analysis

In empirical research the framework for data analysis comprises data description and data analysis (Biggam 2011, p.158). The former has to do with summary statistics about the data; while the latter, involves empirical experiment to test the hypothesis of the research. In this paper we used bivariate descriptive statistics; line (trend) graphs to identify patterns or trends enable an understanding of uncertain events in the past concerning WTI price and inventories and also predict future events about these variables. By comparing data for each independent variable with the dependent variable (WTI crude oil price), it was possible to summarize the relationship between these variables. It is acknowledged however that, trend analysis does not provide sufficient information for testing the hypothesis of an experiment. Consequently, a range of econometric tests were carried out in our analysis as follows.

2.2.1. Regression Analysis

We applied regression analysis to estimate the relationship between all independent and dependent variables in order to establish the importance of the inventories for the WTI price. This enabled an understanding of the responses of the WTI price to individual changes in any one of the independent variables. This test also helped to establish the significance of relationships of the independent variable to the WTI price. The following models were specified and applied to the respective objectives of the paper.

To estimate the relative weight of US crude oil inventory on WTI crude oil prices from 1993 to 2013 the following OLS model was applied. The WTI price model:

$$WTI = \alpha + \beta_1 PROD + \beta_2 GDP + \beta_3 CONS + \beta_4 INV + \beta_5 REX + \beta_6 OPINT + \varepsilon \qquad (1)$$

where,
α = constant (intercept)
β1 to β6 = coefficients of the six independent variables
ε = residual

Because this is a fitted model, residual instead of error term was used. The residual is the difference between each data in the sample and the observable sample mean. In order to ensure meaningful interpretation of the coefficients, the model was transformed to log-linear (double-log or constant elasticity) model by converting the regressors and the regressand (dependent variable) into a logarithmic form. A remarkable feature about the log-linear model is that the slope coefficients can be interpreted as elasticities (Koop, 2013). 'The advantage with elasticities is that they are pure numbers devoid of units in which the variables are measured such as dollars and thousands of barrels because they are ratios of percentage changes' (Gujarati, 2011, p.26). Therefore the OLS regression model (1) was re-specified as follows:

$$LOG(WTI) = \alpha + \beta_1 LOG(PROD) + \beta_2 LOG(GDP) + \beta_3 LOG(CONS) + \beta_4 LOG(INV) + \beta_5 LOG(REX) + \beta_6 LOG(OPINT) + \varepsilon \quad (2)$$

Time series data were mostly used for our analysis. Although time series data, when used for regression analysis, usually cause the problem of autocorrelation (Gujarati, 2011, p.97), a common remedial action is to transform the level from regression (2) to first-difference; this is denoted by Δ or D. Consequently, (2) was transformed to first-difference order and was re-specified as follows:

$$\Delta LOG(WTI) = \alpha + \beta_1 \Delta LOG(PROD) + \beta_2 \Delta LOG(GDP) + \beta_3 \Delta LOG(CONS) + \beta_4 \Delta LOG(INV) + \beta_5 \Delta LOG(REX) + \beta_6 \Delta LOG(OPINT) + \varepsilon \quad (3)$$

or

$$DLOG(WTI) = \alpha + \beta_1 DLOG(PROD) + \beta_2 DLOG(GDP) + \beta_3 DLOG(CONS) + \beta_4 DLOG(INV) + \beta_5 DLOG(REX) + \beta_6 DLOG(OPINT) + \varepsilon \quad (4)$$

Before the results of the model were interpreted, the model was critically evaluated using residual diagnostics via multicollinearity, autocorrelation, model specification errors and heteroscedasticity tests. Subsequently, after the results were interpreted, the research hypothesis was evaluated based on the evidence from the test.

To investigate the future impact of changes in US crude oil inventory level on WTI crude oil prices, (5) was used in an Ex-post forecasting to predict the dependent variable from 2011 to 2013. This allowed a comparison of the forecast WTI prices with the actual prices during that same period since the data was available and known. The experiment enabled an evaluation of the predictive power of the model. However, the drawback to the method was that the results only revealed information about the efficiency of the model for forecasting (i.e. it showed the predictive power of all the regressor jointly), but did not provide information about the contribution or significance of each regressor on the regard. Therefore it was difficult to determine the future impact of changes in U.S. crude oil inventories on WTI crude oil prices. To tackle this problem, two models were used for Ex-post forecasting of WTI crude oil prices. The first model included U.S. crude oil inventories (INV) while the second did not. By doing this, it was possible to compare both models in order to ascertain whether the inclusion of U.S. crude oil inventories better predicts WTI crude oil price movement in the future or not. The two regression models that were used for Ex-post forecasting were the test and control forecasting models below:

The test forecasting model;

$$DLOG(WTI) = \alpha + \beta_1 DLOG(PROD) + \beta_2 DLOG(GDP) + \beta_3 DLOG(CONS) + \beta_4 DLOG(INV) + \beta_5 DLOG(REX) + \beta_6 DLOG(OPINT) + \varepsilon \quad (5)$$

The control forecasting model;

$$DLOG(WTI) = \alpha + \beta_1 DLOG(PROD) + \beta_2 DLOG(GDP) + \beta_3 DLOG(CONS) + \beta_4 DLOG(REX) + \beta_5 DLOG(OPINT) + \varepsilon \quad (6)$$

The results of the forecast were evaluated using basic measures such as RMSE, MAE, MAPE and Theil Inequality Coefficient[1]. Thereafter the results of both models were compared using these aforementioned measures as well as tables and line graphs to compare the forecast and actual WTI prices. The research hypothesis was then either rejected or accepted based on the comparison.

[1] Further information about test results is available on request.

In order to establish the short run effect of US crude oil inventories on WTI crude oil price, a Vector Error Correction Model (VECM) was established. The VECM model is popularly used for analyzing long and short-run causal relationship between variables (Koop, 2013). The regression models did not provide information about causal relationships. Unlike regression analysis, the VECM has been known to have causal relationship predictability. It is capable of showing both long and short run relationship and was therefore useful for this analysis. The idea behind the vector error correction model is the notion that a deviation of variables in its current state from its long-run relationship will be fed into its short-run relationship. According to Gujarati (2011, p.232) the VECM model "postulates that changes in the dependent variable depend on changes in the independent variable and the lagged equilibrium error term".

This led to the formation of another research hypothesis:

Hypothesis 3

H0 = There is no short-run relationship between U.S. crude oil Inventory level and WTI crude oil prices from 1993 to 2013.

H1 = There is a short-run relationship between U.S. crude oil Inventory level and WTI crude oil prices from 1993 to 2013.

3. Results

3.1. Implications of U.S. Crude Oil Inventory for Movement in WTI Crude Oil Prices

Results of the residual diagnostics, presented in Figure 1, indicate that the OLS model does not suffer from multicollinearity, heteroscedasticity, autocorrelation, and model misspecification.

First, the result of pairwise correlations which was conducted for multicollinearity indicates only one high pairwise correlation of 0.82 between DLOG (PROD) and DLOG (CONS). Furthermore, the model was characterized by low R2 of 0.24 in which half (½) of the t ratios are statistically significant. It was therefore safe to conclude that the model does not suffer from the problem of multicollinearity Second, the Breusch-Pagan and White test of Heteroscedasticity were conducted, and the results indicated the model does not suffer the problem of Heteroscedasticity. Last, the result of a durbin-watson statistics of 1.73 was close to 2, hence the model does not suffer from autocorrelation and the p value of a Breusch-Godfrey test was (0.07) implying that the null hypothesis cannot be rejected at 95% confidence interval; hence the residuals are not autocorrelated.[2]

Table 1. OLS Multiple Regression Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.0035	0.0059	0.5820	0.5612
DLOG(PROD)	-0.1981	0.1598	-1.2396	0.2165
DLOG(GDP)	1.1195	0.7961	1.4061	0.1612
DLOG(CONS)	0.2579	0.1651	1.5622	0.1198
DLOG(INV)	-0.4671	0.1687	-2.7699	0.0061
DLOG(REX)	-2.5381	0.5809	-4.3691	0.0000
DLOG(OPINT)	0.5618	0.1086	5.1743	0.0000
R-squared	0.24	Mean dependent var		0.0073
Adjusted R-squared	0.22	S.D. dependent var		0.0841
S.E. of regression	0.074	Akaike info criterion		-2.333
Sum squared resid	1.139	Schwarz criterion		-2.223
Log likelihood	256.61	Hannan-Quinn criter.		-2.288
F-statistic	11.103	Durbin-Watson stat		1.730
Prob(F-statistic)	0.0000			

[2] Further information about tests is available on request.

3.1.1. R^2 (Fitness of the Regression Model)

The results of the estimated regression (Table 1) presented an R^2value of 0.24. However, because of the limitation of the R^2, the value of the *adjusted* R^2 (0.22 / 22%) was preferred for measuring the fitness of the regression line. By implication only 22% of total variation in *DLOG (WTI)* is explained by all the regressors of the regression model. Typically, any value of R^2 / *adjusted* R^2 that is close to zero indicates a bad fit of the model. However, because the purpose of objective (II) was to estimate the relative weight of just U.S. crude oil market activities on global WTI crude oil price benchmark, a low *adjusted* R^2 was to be expected because variation in the global crude oil price benchmark (WTI) is determined by global activities and not just an individual country (EIA 2015). Therefore an adjusted R^2 value of 0.22 is interpreted as:

22% of the variation in WTI crude oil price between 1993 and 2013 can be explained by changes in the U.S. crude oil market activities.

3.1.2. F-statistics (Hypothesis Test of R^2)

The result of the F-test and its accompanying probability are 11.10 and 0.00 respectively. Since the F-test is used to test the overall significance of the regression (hypothesis test to find out if all the regressors of the model have 'no impact' on changes in WTI crude oil price) the null hypothesis shall be rejected at 5% significance level and the alternative hypothesis shall be accepted.

H_0 = All the slope coefficients are simultaneously equal to zero

H_1 = All the slope coefficients are simultaneously not equal to zero

This means that the estimated regression model is helpful in explaining the behaviour of the regress. In other words, the variables chosen to explain the changes in WTI crude oil prices are jointly significant.

3.1.3. DLOG (PROD) [β_1]

The regression results in Table 1 reveal that the slope coefficient of DLOG (PROD) [β_1] is negative (-), indicating that DLOG (PROD) and DLOG (WTI) have an inverse relationship. This is in line with economic theory on price as fundamentally, an increase in supply of crude oil is expected to exert a downward pressure WTI price., akin to the reasoning behind the oil price crash of 2014 as hypothesized and believed by most analysts and researchers alike (Fortune 500, 2015; Bloomberg Business, 2015). Therefore holding all other things constant (.i.e. an increase in demand) an increase in supply will 'most likely' lead to a fall in price. Consequently the slope coefficient of DLOG (PROD) from the regression [-0.19] is interpreted as:

1% marginal increase in U.S. crude oil production will tend to decrease WTI crude oil prices by a marginal amount of 0.19%, ceteris paribus.

The results also indicate that WTI exhibits an inelastic relationship to U.S. crude oil production. Nonetheless, the probability of the t-stats for DLOG (PROD) [0.22] indicates that the null hypothesis cannot be rejected; hence, the slope coefficient [β_1] is not statistically significant. In other words, at 5% significance level, we are not confident that a marginal increase of 1% in U.S. crude oil production is associated with a 0.19% marginal decrease in WTI crude oil price *ceteris paribus*.

According to the EIA's International Energy statistics (EIA 2014), the U.S. produced a total of 196,133.2 (thousand bbl/d), between 1993 and 2013, which represented 11.7% of the total daily world production (1,677,665.6 thousand bbl/d) during that period. This represents less than $1/8^{th}$ of global production, which is very small to significantly cause a 0.19% marginal decrease in WTI crude oil price due to a 1% marginal increase.

3.1.4. DLOG (GDP) [β_2]

The second slope coefficient DLOG (GDP) [β_2] has a positive sign (+), which indicates that DLOG (GDP) and DLOG (WTI) have a direct relationship. Again, in line with economic theory it is true that an increase in income would mean more crude oil can be consumed. Again, an increase in economic activity and hence productivity could lead to increase an increase in energy demand (See Huanga *et al.* 2008; Lee and Chang 2008). Therefore holding all other things constant (.i.e. an increase in supply) an increase in income (GDP) will 'most likely' lead to an increase in demand, subsequently increasing prices (indirect relationship). Given the result of slope coefficient (1.1), the regression relationship can be interpreted as:

1% marginal increase in U.S. GDP will tend to increase WTI crude oil prices by a marginal amount of 1.1%.

The value of the slope coefficient also indicates that WTI exhibits a slightly elastic relationship towards U.S. GDP. Nonetheless the probability of the t-stats for DLOG (GDP) [0.16] indicates that the null hypothesis cannot be rejected. This means that the slope coefficient [β_2] is not statistically significant. In other words, at 5% significance level, the researcher is not confident that a 1% marginal increase in U.S. GDP is associated with a 1.1% marginal increase in WTI crude oil price *ceteris paribus.*

The economic conditions and policies in OECD countries such as U.S. have a significant impact on its demand for crude oil. For example, the U.S. is characterised by higher fuel taxes and policies to develop its fuel economy. According to EIA (2014), 'this tends to slow growth in oil consumption even in times of strong economic growth'. Moreover, the U.S. tends to have more service sectors relative to manufacturing sectors, hence; robust economic growth may not have significant impact as it would in non-OECD countries such as China. This may explain why the regression result indicates that marginal changes in U.S. GDP is not statistically significant in explaining marginal changes in WTI crude oil prices.

3.1.5. DLOG (CONS) [β_3]

The third slope coefficient DLOG (CONS) [β_3] has a positive sign (+), which reveals that DLOG (CONS) and DLOG (WTI) have a direct relationship. Holding all other things constant with a proviso that there is a zero change supply of crude oil, an increase in consumption will most likely lead to a fall in price. Consequently the result of the slope coefficient can be interpreted as:

1% marginal increase in U.S. Product Supply of Crude Oil and Petroleum Product will tend to increase WTI crude oil prices by a marginal amount of 0.25%, ceteris paribus.

The value of the slope coefficient also indicates that WTI exhibits an inelastic relationship to U.S. product supply of crude oil and petroleum product. Nonetheless the probability of the t-stats for DLOG (CONS) [0.11] indicates that the null hypothesis cannot be rejected. This means that the slope coefficient [β_3] is not statistically significant. In other words, at 5% significance level, the researcher is not confident that a 1% marginal increase in U.S. Product Supply of Crude Oil and Petroleum Product is associated with a 0.25% marginal increase in WTI crude oil price, *ceteris paribus.*

At first glance, this may be surprising, especially since U.S. crude oil consumption of 384,912.6 thousand bbl/d) accounts for 24.24% (over $1/5^{th}$)of global crude oil consumption (1,587,614.7 thousand bbl/d) between 1993 to 2013 according to EIA's International Energy statistics (EIA 2014). However, because of the economic and structural condition of OECD countries such as U.S, 'it takes time for people to adjust their transportation routines and for the vehicle stock to turnover and become more energy-efficient in response to price changes' (EIA, 2014). This might explain why the regression results indicate statistical insignificance of [β_3]. However this is subject to further investigation.

3.1.6. DLOG (INV) [β_4]

The fourth slope coefficient DLOG (INV) [β_4] has a negative sign (-), which reveals that DLOG (INV) and DLOG (WTI) have an inverse relationship. This corresponds with economic literature that an increase in crude oil inventories would lead to a fall in price (See Ye *et al.* 2005). Furthermore since inventories serve as a balancing scale between demand and supply, it is not surprising; rather it is expected that an increase in crude oil stocks indicates that production outweighs demand, hence a resulting fall in price. Studies such as the EIA's (2015), on global crude oil price drivers, reveal similar association between OECD crude oil inventories and WTI crude oil prices. Therefore holding all other things constant (.i.e. increase in GDP) an increase in U.S. crude oil inventories would most likely lead to a fall in price. Given the result of the slope coefficient (-0.46), the regression relationship can be interpreted as:

1% marginal increase in U.S. Crude Oil Stocks (Non-SPR) will tend to decrease WTI crude oil prices by a marginal amount of 0.46%, ceteris paribus.

The value of the slope coefficient also indicates that WTI exhibits an inelastic relationship towards U.S. product supply of crude oil and petroleum products. The corresponding probability of its *t*-statistics (0.006) reveals that the marginal effect of DLOG (INV) on DLOG (WTI) is strongly statistically significant. Hence at 5% significance level, the researcher is quite confident that a 1% marginal increase in Crude Oil Stocks (Non-SPR) is associated with a 0.46% marginal decrease in WTI crude oil price, *ceteris paribus*. However, it should be noted that an examination of the R^2indicates that this only explains or accounts for 22% of the variability in WTI crude oil prices.

3.1.7. DLOG (REX) [β_5]

The fifth slope coefficient DLOG (REX) [β_5]has a negative sign (-), which reveals that DLOG (REX) and DLOG (WTI) have an inverse relationship. This is not surprising because, an increase in real U.S. Dollar exchange rate would mean that U.S. dollar priced commodities would become more expensive for non-U.S. dollar purchasing countries. Hence, holding all other factors constant, an increase in U.S. real exchange rate would reduce the purchasing power of other countries; which would be reflected by a fall in demand for U.S. dollar priced commodities. Since WTI crude oil is priced in U.S. dollars, this situation would lead to a fall in WTI crude oil, thus leading to a fall in price. Therefore holding all other things constant (.i.e. an increase in supply) an increase in real U.S. dollar exchange rate (REX) would tend to lead to a fall in global demand (non-U.S. exchange rate countries), consequently causing a fall in WTI prices (indirect relationship). Given the slope coefficient of (-2.5), the regression relationship can be interpreted as:

1% marginal increase in Real U.S. exchange rate will tend to decrease WTI crude oil prices by a marginal amount of 2.5%, ceteris paribus.

The value of the slope coefficient also indicates that WTI exhibits an elastic relationship towards real U.S. dollar exchange rates. The corresponding probability of its *t*-statistics (0.000) reveals that the marginal effect of DLOG (REX) on DLOG (WTI) is strongly statistically significant. Hence at 5% significance level, the researcher is quite confident that a 1% marginal increase in real U.S. dollar exchange rate is associated with a 2.5% marginal decrease in WTI crude oil price, *ceteris paribus*. However, it should be noted that an examination of the R^2indicates that this only explains or accounts for 22% of the variability in WTI crude oil prices.

3.1.8. DLOG (OPINT) [β_6]

Finally the sixth slope coefficient DLOG (OPINT) [β_6] also has a positive sign (+), indicating that DLOG (OPINT) and DLOG (WTI) have a direct relationship. Intuitively this is not surprising, since an increase in open interest means an increase in 'buy market orders', which is indicative of an increase in demand. Consequently holding all other things constant an increase in U.S. Crude Oil Futures & Options Market Open Interest will 'most likely' lead to an increase in prices. Given the slope coefficient of (0.56), the regression relationship this can be interpreted as:

1% marginal increase in U.S. Crude Oil Futures & Options Market Open Interest will tend to increase WTI crude oil prices by a marginal amount of 0.56%, ceteris paribus.

The value of the slope coefficient also indicates that WTI exhibits an inelastic relationship towards U.S. Crude Oil Futures & Options Market Open Interest. The corresponding probability of its *t*-statistics (0.000) reveals that the marginal effect of DLOG (OPINT) on DLOG (WTI) is strongly statistically significant. Hence at 5% significance level, the researcher is quite confident that a 1% marginal increase in U.S. Crude Oil Futures & Options Market Open Interest is associated with a 0.56% marginal increase in WTI crude oil price, *ceteris paribus*. However, it should be noted that an examination of the R^2 indicates that this only explains or accounts for 22% of the variability in WTI crude oil prices.

3.2. Future Impact of Changes in U.S. Inventory Level on WTI Crude Oil Prices

To investigate the future impact of changes in U.S. inventory level on WTI crude oil prices two Ex-post forecasts models (Test and Control) were developed using data from 1993 to 2010 to forecast WTI crude oil prices from 2011 to 2013 as indicated in (5) and (6). Due to the lack of data on OPINT from 2012M12 to 2013M2, the forecast range is limited from 2011M01 to 2012M11. The estimated results of test and control regression model estimates are presented in Figures 1 to 4.

3.2.1. Results of the Forecast WTI prices - Test and Control Experiments

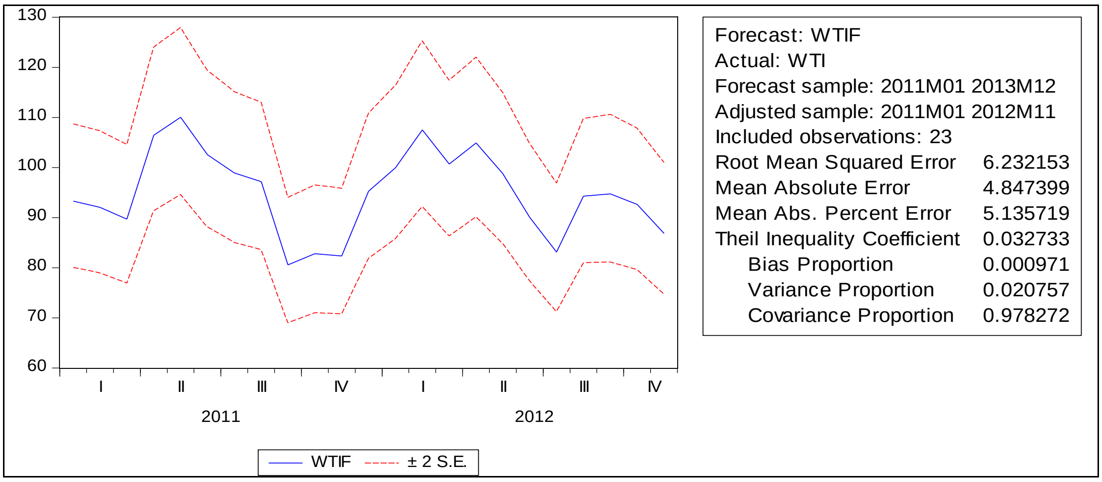

Figure 1. WTI Ex-Post Forecast Result of Test Model (2011-2012)

The thick red lines in Figures 1 and 2 indicate the movement of WTI over the forecasted trajectory while the dotted lines represent 95% confidence lines. Based on both graphs, we present 95% confidence in the forecasted regression line (movement) of WTI. However this does not provide enough information for comparison between the test and control results. Given that both results have similar observations (23), the RMS error, MAE, MAPE and Theil Inequality Coefficient can be used for comparison. The Test forecast results (see Figure 1) presented lower figures for all aforementioned measures of error when compared to the forecast results of the Control model (see Figure 4). This means that using INV to forecast WTI amongst the other control variables will provide better predictions than otherwise.

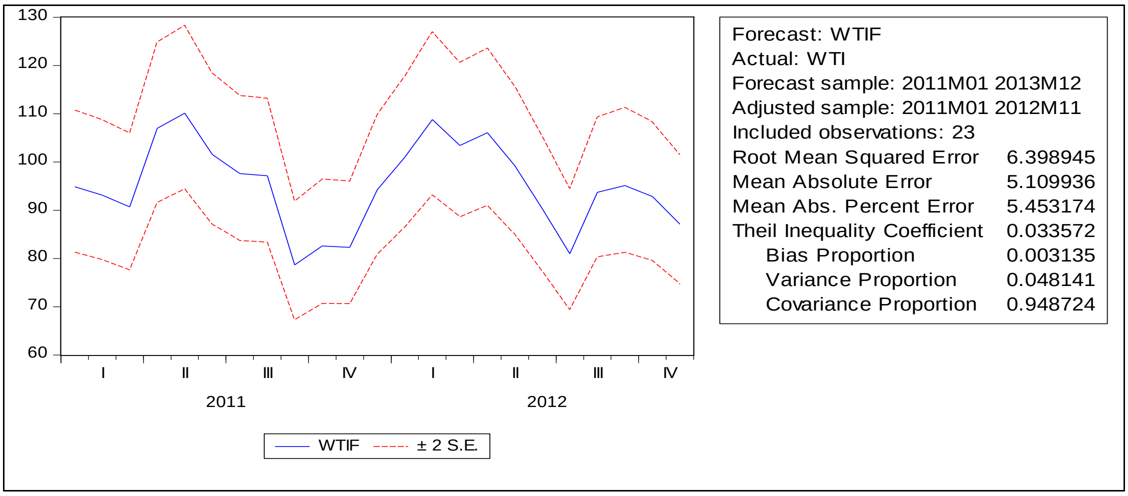

Figure 2. WTI Ex-Post Forecast Result of Control Model (2011-2012)

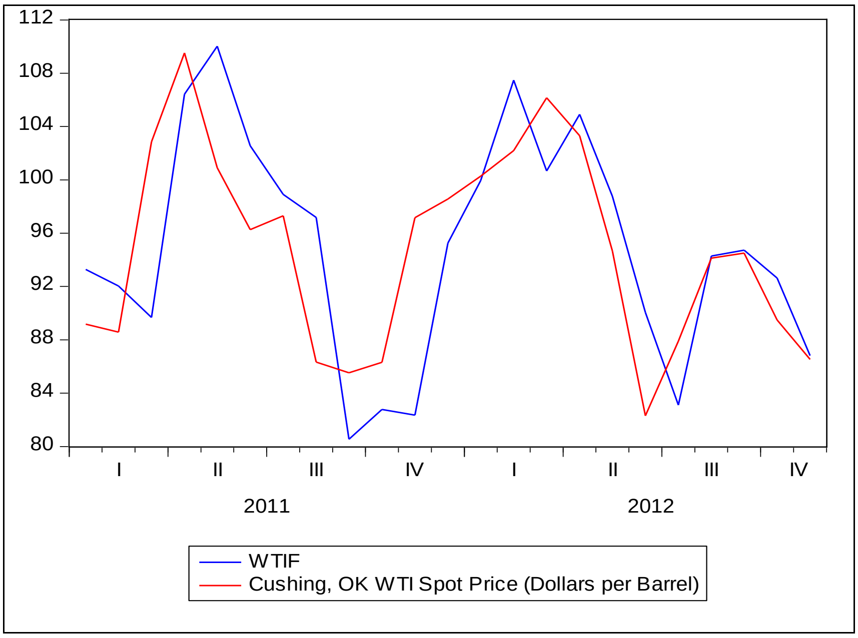

Figure 3. Graphs of Actual WTI and Forecasted WTI Graphs of (Test Model) (2011-2012)

To test the predictive power of both forecasts, two line graphs were plotted (see Figures 3 and 4) to compare the actual WTI values with the forecasted WTI values. In general the graphs reveal good but similar predictive powers of both the test and control models. However Table 2 reveals a better predictive power of the test model over the control model. From the table it is clear than the average of the test forecast is much closer to the actual average price of WTI than the control with $0.19 difference in the former and $0.36 in the latter.

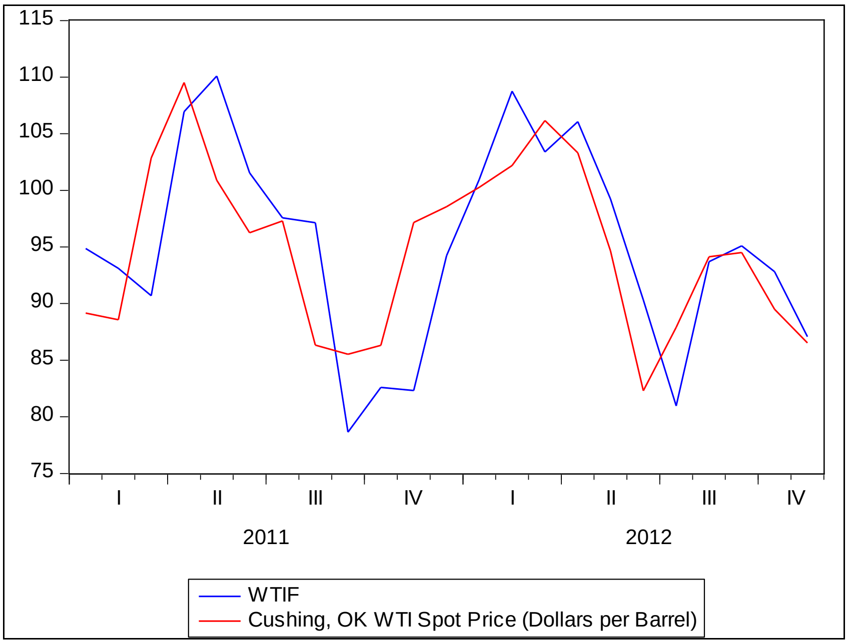

Figure 4. Graphs of Actual WTI and Forecasted WTI (Control Model) (2011-2012)

Table 2. Actual and forecasted WTI results using test and control models (2011-2012)

Date	Test Experiment				Control Experiment		
	WTIF *Forecast*	WTI *Actual*	Difference		WTIF *Forecast*	WTI *Actual*	Difference
2011M01	93.27	89.17	4.10		94.87	89.17	5.70
2011M02	92.04	88.58	3.46		93.12	88.58	4.54
2011M03	89.68	102.86	-13.18		90.69	102.86	-12.17
2011M04	106.43	109.53	-3.10		106.94	109.53	-2.59
2011M05	110.02	100.90	9.12		110.10	100.90	9.20
2011M06	102.55	96.26	6.29		101.55	96.26	5.29
2011M07	98.91	97.30	1.61		97.57	97.30	0.27
2011M08	97.18	86.33	10.85		97.15	86.33	10.82
2011M09	80.54	85.52	-4.98		78.65	85.52	-6.87
2011M10	82.77	86.32	-3.55		82.59	86.32	-3.73
2011M11	82.35	97.16	-14.81		82.31	97.16	-14.85
2011M12	95.26	98.56	-3.30		94.24	98.56	-4.32
2012M01	99.95	100.27	-0.32		100.96	100.27	0.69
2012M02	107.48	102.20	s5.28		108.76	102.20	6.56
2012M03	100.67	106.16	-5.49		103.40	106.16	-2.76
2012M04	104.91	103.32	1.59		106.06	103.32	2.74
2012M05	98.76	94.66	4.10		99.25	94.66	4.59
2012M06	90.05	82.30	7.75		90.31	82.30	8.01
2012M07	83.11	87.90	-4.79		80.97	87.90	-6.93
2012M08	94.29	94.13	0.16		93.71	94.13	-0.42
2012M09	94.73	94.51	0.22		95.10	94.51	0.59
2012M10	92.63	89.49	3.14		92.83	89.49	3.34
2012M11	86.82	86.53	0.29		87.08	86.53	0.55
Average	**94.98**	**94.78**	**0.19**		**95.14**	**94.78**	**0.36**

3.3. Evaluating the Short Run Relationship between U.S. Crude Oil Inventories and WTI Price

The foundation of this paper was to evaluate the short-run relationship between changes in U.S. crude oil inventories and changes in WTI crude oil price from 1993 to 2013. This section presents the results of our investigation of a potential short-run relationship using a VECM.

3.3.1. Unit Root (Stationarity) Test

A prerequisite before running the VECM analysis is to verify if the variables are stationary or not. The problem with non-stationary time series is that "their behaviour can only be studied for the period under consideration, therefore it is not possible to generalise the deductions to other time periods" (Gujarati, 2011, p.207).

Table 3. Summary of unit-root test results

Variables	**Unit Root Test At**	
	Level	**First Difference**
LOG(WTI)	NON-STATIONARY	STATIONARY
LOG(PROD)	NON-STATIONARY	STATIONARY
LOG(GDP)	NON-STATIONARY	STATIONARY
LOG(CONS)	NON-STATIONARY	STATIONARY
LOG(INV)	STATIONARY	STATIONARY
LOG(REX)	NON-STATIONARY	STATIONARY
LOG(OPINT)	NON-STATIONARY	STATIONARY

Table 3 summarizes the unit-root test results. The results show that all the variables except for INV are non-stationary at level but stationary at first difference.

3.3.2. Cointegration Test

Since the variables are integrated in same order (after first difference), cointegration test was conducted to determine long-run association or equilibrium. The result from the Johansen test of cointegration (Trace test and Maximum Eigen value) revealed that regressing these non-stationary time series variables against one another will not result in spurious regression because they are cointegrated (see Table 4). This shows that the variables of the model share a common stochastic trend and tend to grow proportionally. In other words, they move together in the long run, that is; "there is a long-term or equilibrium relationship between them" (Gujarati, 2014, p.224). Further tests; Grangers Causality test and Wald tests were conducted to determine the presence of short-run relationship.

Table 4. Johansen cointegration test results

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.2530	174.195	125.61	0.0000
At most 1 *	0.1655	113.809	95.754	0.0016
At most 2 *	0.1372	76.3582	69.819	0.0137
At most 3	0.1076	45.821	47.856	0.0767
At most 4	0.0735	22.245	29.797	0.2851
At most 5	0.0275	6.4297	15.494	0.6447
At most 6	0.0031	0.6485	3.8415	0.4206

Notes: Trace test indicates 3 cointegratingeqn (s) at the 0.05 level
* Denotes rejection of the hypothesis at the 0.05 level
** MacKinnon-Haug-Michelis (1999)

Table 4. (continued)

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.2530	60.385	46.231	0.0009
At most 1	0.1655	37.451	40.078	0.0960
At most 2	0.1372	30.537	33.877	0.1190
At most 3	0.1076	23.575	27.584	0.1503
At most 4	0.0735	15.816	21.131	0.2358
At most 5	0.0275	5.7812	14.264	0.6415
At most 6	0.0031	0.6485	3.8415	0.4206

Notes: Max-eigenvalue test indicates 1 cointegratingeqn(s) at the 0.05 level
* Denotes rejection of the hypothesis at the 0.05 level
** MacKinnon-Haug-Michelis (1999) p-values

3.3.3. VECM Estimates Using OLS

To determine the 'short-run' effect of U.S crude oil inventories on WTI crude oil prices a Vector Error Correction Model (VECM) was established to analyze the long and short-run causal relationship between variables. The idea behind the vector error correction model is the notion that a deviation of variables in its current state from its long-run relationship will be fed into its short-run relationship. From the results of the test, the VECM model estimates for WTI were regressed using OLS to provide relevant estimates for our investigation. The first coefficient of OLS-VECM results (Table 5), C (1) was statistically significant at 5% significance and is negative (-), implying a long-run relationship between all the variables as verified by the results of cointegration. However, results of the Wald test indicate that there is no short-run relationship running from 7 joint lags of any of the independent variables to WTI (see Appendix C). The number of lags selected for the VECM model was from the Lag selection criteria test (see Appendix B)

Table 5. Results of OLS-VECM multiple regression model[3]

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.1367	0.0479	-2.8502	0.0051
C(2)	0.0099	0.0962	0.1033	0.9179
C(3)	0.7025	0.3759	1.8692	0.0638
C(4)	0.3258	0.1089	2.9899	0.0033
C(5)	0.1494	0.1102	1.3546	0.1779
C(17)	0.1021	0.2806	0.3637	0.7167
R-squared	0.368	Mean dependent var		0.0087
Adjusted R-squared	0.117	S.D. dependent var		0.0868
S.E. of regression	0.082	Akaike info criterion		-1.9378
Sum squared resid	0.872	Schwarz criterion		-1.0117
Log likelihood	231.274	Hannan-Quinn criter.		-1.5624
F-statistic	1.4655	Durbin-Watson stat		2.0123
Prob(F-statistic)	0.0428			

3.3.4. Grangers Causality Test

To verify the deduction of no short-run relationship, Grangers Causality test was conducted on the VECM model. The results of the VEC Grangers Causality Test indicate that at 5%

[3] Further detail available on request.

significance level, the null hypothesis cannot be rejected for any of the explanatory variables (see Table 6). This also means that there is no short-run relationship between any of the explanatory variables and WTI. Hence the results of regression represent just correlation relationship and not casual relationships between the independent variables and WTI crude oil prices. However, together the independent variables cause WTI crude oil price movement as indicated by the presence of a long-run or equilibrium relationship. Our evidence therefore contradicts literary perception that there is a short-run relationship between U.S. crude oil inventories and WTI crude oil prices put forward by Ye *et al.*2005; Rifflart and Chevillon (2009), Biu (2011), Schmidbauer and Rosch (2012), Cashin*et al.* (2014) and Guntner (2014).

Table 6. VEC Granger causality test result [4]

Excluded	Chi-sq	df	Prob.
D(LOG(PROD))	6.282737	7	0.5072
D(LOG(GDP))	9.830095	7	0.1984
D(LOG(CONS))	6.894556	7	0.4399
D(LOG(INV))	13.39641	7	0.0630
D(LOG(REX))	4.348354	7	0.7389
D(LOG(OPINT))	11.20870	7	0.1298
All	55.00320	42	0.0861

Note: Dependent variable: D (LOG (WTI))

3.4. Research Hypotheses

The purpose of this experiment was to test the research hypothesis specified in section 2. The first regression revealed that a '1% marginal increase in U.S. Crude Oil Stocks (Non-SPR) will tend to decrease WTI crude oil prices by a marginal amount of 0.46%, ceteris paribus'. This indicates that for the null hypothesis (H_0) for the first experiment shall be rejected. Hence, U.S. crude oil inventories amongst other significant variables explain WTI crude oil prices overtime. Furthermore, the results of the Ex-post forecasts indicate that the inclusion of U.S. crude oil inventories amongst other significant variables to forecasts WTI crude oil price movements results in better prediction than if not included. Therefore for the second experiment hypothesis, the null hypothesis (H_0) shall also be rejected. Hence there is a future impact of changes in U.S. inventory level on WTI crude oil prices using data from 1993 to 2013. Finally the evaluation of short-run analysis revealed that there is no short-run relationship running from U.S. crude oil inventory to WTI crude oil prices. Therefore for the third research hypothesis, the null hypothesis (H_0) shall be accepted.

4. Conclusion

The focus of this research was twofold: first to 'estimate the relative weight of U.S. crude oil inventory amongst other significant explanatory variables in explaining the movement of WTI crude oil prices overtime. It has been widely recorded in the literature on crude oil price and inventories that changes in WTI crude oil prices are a reflection of changes in OECD crude oil inventories following the theory that inventories serve as an intermediary between crude oil demand and supply. The veracity of this theory was tested using U.S. crude oil inventories amongst other relevant explanatory variables. The result of empirical analysis using OLS regression revealed this to be true even for an individual country such as the U.S. US represents the largest crude oil producing and consuming country (EIA, 2014), therefore following the theory of price determination, changes in U.S. crude oil inventories can explain a portion of changes in WTI crude oil prices.

[4] VEC Grangers Causality Hypothesis Test for Short-Run Relationship: *H0* = Independent variable does not cause dependent variable, *H1* = Independent variable causes dependent variable.

Second was to "investigate the future impact of changes in U.S. inventory level on WTI crude oil prices using historical data from 1993 to 2013". This was motivated by the work of Ye*et al.* (2005) which suggested that OECD crude oil inventories can be used to forecast WTI crude oil prices. The usefulness of this work was applied for an individual country such as the U.S. using an OLS regression model rather than an autoregressive model which earlier authors used. Based on Ex-post forecasting, our empirical results indicate that U.S. crude oil inventories can be used to forecast WTI crude oil prices. As stated earlier, because U.S. inventories reveal swings in production and consumption of crude oil and U.S. is also a major consumer and producer of crude oil, its inventories can serve as a signal for changes in WTI crude oil prices, thus, suitable for forecasting future prices.

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APPENDIX A

Table A.1. Ex-Post Forecast OLS Model Estimates

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.0041	0.0064	0.6540	0.5139
DLOG(PROD)	-0.2769	0.1712	-1.6175	0.1075
DLOG(GDP)	0.9298	0.8409	1.1057	0.2703
DLOG(CONS)	0.3068	0.1762	1.7414	0.0833
DLOG(INV)	-0.4467	0.1785	-2.5022	0.0132
DLOG(REX)	-2.6089	0.6142	-4.2480	0.0000
DLOG(OPINT)	0.5931	0.1143	5.1888	0.0000
R-squared	0.2562	Mean dependent var		0.0084
Adjusted R-squared	0.2320	S.D. dependent var		0.0857
S.E. of regression	0.0751	Akaike info criterion		-2.3035
Sum squared resid	1.0383	Schwarz criterion		-2.1843
Log likelihood	226.986	Hannan-Quinn criter.		-2.2552
F-statistic	10.564	Durbin-Watson stat		1.7204
Prob(F-statistic)	0.0000			

Notes: Dependent Variable: DLOG(WTI), Method: Least Squares. Date: 08/04/14 Time: 20:08. Sample (adjusted): 1995M02 2010M12. Included observations: 191 after adjustments.

Table A.2. Estimated Forecast (TEST) Model for WTI

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.0055	0.0064	0.8532	0.3946
DLOG(PROD)	-0.3838	0.1681	-2.2836	0.0235
DLOG(GDP)	0.5533	0.8389	0.6595	0.5104
DLOG(CONS)	0.3808	0.1762	2.1621	0.0319
DLOG(REX)	-2.7431	0.6204	-4.4212	0.0000
DLOG(OPINT)	0.6040	0.1158	5.2143	0.0000
R-squared	0.2309	Mean dependent var		0.0084
Adjusted R-squared	0.2101	S.D. dependent var		0.0857
S.E. of regression	0.0762	Akaike info criterion		-2.2805
Sum squared resid	1.0736	Schwarz criterion		-2.1784
Log likelihood	223.79	Hannan-Quinn criter.		-2.2392
F-statistic	11.109	Durbin-Watson stat		1.6397
Prob(F-statistic)	0.0000			

Notes: Dependent Variable: DLOG(WTI), Method: Least Squares. Date: 08/04/14 Time: 20:23, Sample (adjusted): 1995M02 2010M12, Included observations: 191 after adjustments.
Source: Eviews 8

APPENDIX B

VAR LAG Order Selection Criteria

Table B.1. VAR Lag Order Selection Criteria for VECM

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1387.365	NA	3.81e-15	-13.337	-13.224	-13.291
1	3308.858	3694.465	5.29e-23	-31.429	-30.526*	-31.063
2	3409.673	187.0189	3.21e-23	-31.929	-30.238	-31.246
3	3528.117	211.7104	1.65e-23	-32.600	-30.121	-31.597
4	3626.006	168.3507	1.04e-23	-33.072	-29.804	-31.750*
5	3685.346	98.04055	9.48e-24	-33.172	-29.115	-31.531
6	3744.505	93.73987	8.75e-24	-33.271	-28.425	-31.311
7	3818.517	112.2689*	7.05e-24*	-33.512*	-27.877	-31.234
8	3857.088	55.89962	8.07e-24	-33.412	-26.987	-30.814

Notes: VAR Lag Order Selection Criteria, Endogenous variables: LOG(WTI) LOG(PROD) LOG(GDP, LOG(CONS) LOG(INV) LOG(REX) LOG(OPINT). Exogenous variables: C. Date: 07/23/14 Time: 23:49. Sample: 1993M01 2013M12, Included observations: 207. * indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion.

APPENDIX C

Wald Test for Short-Run Relationship/Causality

Wald Test Hypothesis:

H_0 = No short-run relationship with dependent variable
H_1 = Short-run relationship with dependent variable

PROD = C(11)=C(12)=C(13)=C(14)=C(15)=C(16)=C(17)=0

Wald Test:
Equation: EQ02

Test Statistic	Value	df	Probability
F-statistic	0.6209	(7,131)	0.7379
Chi-square	4.3466	7	0.7391

GDP = C(18)=C(19)=C(20)=C(21)=C(22)=C(23)=C(24)=0

Wald Test:
Equation: EQ02

Test Statistic	Value	df	Probability
F-statistic	1.0674	(7,131)	0.3881
Chi-square	7.4717	7	0.3815

CONS = C(25)=C(26)=C(27)=C(28)=C(29)=C(30)=C(31)=0

Wald Test: Equation: EQ02			
Test Statistic	Value	df	Probability
F-statistic	0.5414	(7, 131)	0.8018
Chi-square	3.7894	7	0.8037

INV = C(32)=C(33)=C(34)=C(35)=C(36)=C(37)=C(38)=0

Wald Test: Equation: EQ02			
Test Statistic	Value	df	Probability
F-statistic	1.7673	(7, 131)	0.0991
Chi-square	12.371	7	0.0890

REX = C(39)=C(40)=C(41)=C(42)=C(43)=C(44)=C(45)=0

Wald Test: Equation: EQ02			
Test Statistic	Value	df	Probability
F-statistic	0.2765	(7, 131)	0.9621
Chi-square	1.9356	7	0.9633

OPINT = C(46)=C(47)=C(48)=C(49)=C(50)=C(51)=C(52)=0

Wald Test: Equation: EQ02			
Test Statistic	Value	df	Probability
F-statistic	1.4710	(7, 131)	0.1827
Chi-square	10.303	7	0.1720

APPENDIX D

VEC Grangers Causality Test

Table D.1. VEC Grangers Causality Test Results

Dependent variable: D(LOG(WTI))			
Excluded	Chi-sq	df	Prob.
D(LOG(PROD))	6.2827	7	0.5072
D(LOG(GDP))	9.8300	7	0.1984
D(LOG(CONS))	6.8946	7	0.4399
D(LOG(INV))	13.396	7	0.0630
D(LOG(REX))	4.3483	7	0.7389
D(LOG(OPINT))	11.208	7	0.1298
All	55.003	42	0.0861

Dependent variable: D(LOG(PROD))

Excluded	Chi-sq	df	Prob.
D(LOG(WTI))	4.6062	7	0.7079
D(LOG(GDP))	12.369	7	0.0890
D(LOG(CONS))	25.965	7	0.0005
D(LOG(INV))	10.048	7	0.1859
D(LOG(REX))	6.7338	7	0.4571
D(LOG(OPINT))	7.5263	7	0.3762
All	92.252	42	0.0000

Dependent variable: D(LOG(GDP))

Excluded	Chi-sq	df	Prob.
D(LOG(WTI))	12.956	7	0.0732
D(LOG(PROD))	31.297	7	0.0001
D(LOG(CONS))	32.065	7	0.0000
D(LOG(INV))	13.548	7	0.0598
D(LOG(REX))	6.5962	7	0.4721
D(LOG(OPINT))	21.520	7	0.0031
All	96.600	42	0.0000

Dependent variable: D(LOG(CONS))

Excluded	Chi-sq	df	Prob.
D(LOG(WTI))	4.4184	7	0.7305
D(LOG(PROD))	34.147	7	0.0000
D(LOG(GDP))	13.945	7	0.0522
D(LOG(INV))	49.699	7	0.0000
D(LOG(REX))	8.6489	7	0.2789
D(LOG(OPINT))	7.1364	7	0.4148
All	164.29	42	0.0000

Dependent variable: D(LOG(INV))

Excluded	Chi-sq	df	Prob.
D(LOG(WTI))	14.301	7	0.0461
D(LOG(PROD))	15.586	7	0.0292
D(LOG(GDP))	17.792	7	0.0129
D(LOG(CONS))	16.425	7	0.0215
D(LOG(REX))	9.8633	7	0.1964
D(LOG(OPINT))	22.880	7	0.0018
All	120.01	42	0.0000

Dependent variable: D(LOG(REX))

Excluded	Chi-sq	df	Prob.
D(LOG(WTI))	7.3807	7	0.3903
D(LOG(PROD))	17.603	7	0.0139
D(LOG(GDP))	8.5797	7	0.2843
D(LOG(CONS))	15.882	7	0.0262
D(LOG(INV))	11.889	7	0.1043
D(LOG(OPINT))	7.1339	7	0.4151
All	56.949	42	0.0617

Dependent variable: D(LOG(OPINT))

Excluded	Chi-sq	df	Prob.
D(LOG(WTI))	16.661	7	0.0197
D(LOG(PROD))	9.7344	7	0.2041
D(LOG(GDP))	16.671	7	0.0196
D(LOG(CONS))	6.3065	7	0.5044
D(LOG(INV))	16.969	7	0.0176
D(LOG(REX))	5.0984	7	0.6480
All	59.970	42	0.0355

Notes: VEC Granger Causality/Block Exogeneity Wald Tests, Date: 07/29/14 Time: 13:08, Sample: 1993M01 2013M12, Included observations: 207
Source: Eviews 8

VEC Grangers Causality Hypothesis Test for Short-Run Relationship[5]

H_0 = Independent variable does not cause dependent variable
H_1 = Independent variable causes dependent variable

[5] Further test results are available on request.