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EXPLORING THE CAUSAL RELATIONSHIP BETWEEN OIL MARKETS USING TETRAD PC ALGORITHM

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ABSTRACT

Crude oil price dynamics determines the order of the world oil market in which OPEC and Non OPEC countries plays major role as exporters and importers. The co-integration and information flow of crude oil price between these groups of countries is helpful in understanding the oil price dynamics in terms of oil rich and oil dependent countries. In this empirical study we explored whether or not the selected OPEC and non OPEC countries are co integrated, if so what kind of causal information implies between each other and country's dependence or independence in terms of price giver or price taker. Econometrics tools and causal data analysis software is used in the analysis of oil price time series data.

Keywords:- *Crude Oil Price, Causal data analysis, Co-integration, Econometrics.*

I. INTRODUCTION

The oil market has puzzled many, be it researchers, merchants or even speculators. The era when the oil prices were not volatile have long gone by. Since the year 2000 the prices of oil has lurched from that of a consistent rise to a gradual hike and touched pinnacle in mid 2008. The fundamental reason based on the economic viewpoint is demand supply gap. Though this is one prominent factor that spike up the oil prices, but there are other considerations as well. One can always ask, what role does OPEC play in influencing the prices of oil? Will emerging economies like India and China put further pressure on Oil prices? Answers to these questions can provide readers with most if not all of the significant aspect of oil market.

According to (Adelman, 2004) real problems of oil prices were faced after 1970 because of cartel behaviour. OPEC cartel derived its power not only from geographic concentration of oil resources near the Persian Gulf, but also from the fact that exploration, production and development is in the hands of few sate oil companies (Pirog, 2007). However, this view was opposed by some researchers who through their empirical findings proved that OPEC does not behave as cartel. A.F. Alhajji, David Huettner (1998) in their study on OPEC and other commodity cartels: a comparison concluded that none of the characteristic of cartel behaviour exists in OPEC; monitoring, quota system, punishment system, side payments, buffer stock, cartel authority. Cremer and Isfahani, (1991) in their study explained that the way oil prices behave and output of oil is unrelated to the way a commodity should behave in a cartel of monopolistic pattern.

Many researchers who believe that OPEC is not a cartel argue that Saudi Arabia is a dominant producer among all the member countries that come under OPEC. Many studies were carried out explaining the same dominance of Saudi Arabia on other members including (Mabro (1975), Erickson (1980), Plaut (1981), and Singer (1983). Others believe that political factors increased oil prices and that prices were sustained because of the limited absorptive capacity of OPEC members. These studies include Ezzati (1976, 1978), Teece (1982), and Salehi-Isfahani (1987) among others. For some economists, the international oil market is competitive and speculation, panic and market inefficiency caused the oil crisis. Bohi and Toman (1993) believe that OPEC has not been elective in using its potential monopoly power.

Hitherto, a rich body of literatures on oil market interaction can be found that are mainly involved with two aspects. One is to conduct empirical studies on interactions among diverse oil markets (Ewing, Malik, & Ozfidan, 2002; Hammoudeh, Li, & Jeon, 2003; Jiao, Fan, Wei, Han, & Zhang, 2007; Jiao, Fan, Zhang, & Wei, 2005; Lin & Tamvakis, 2001; Ng & Pirrong, 1996), and the other is concerned with the relationship between financial markets (especially the stock markets) and oil markets (Basher&Sadorsky, 2006; Chen, Roll,&Ross, 1986; Faff&Brailsford,

International Journal of Engineering Researches and Management Studies

1999; Hamao, 1988; Hammoudeh & Eleisa, 2004; Huang, Masulis, & Stoll, 1996; Papapetrou, 2001; Sadorsky, 1999, 2003).

Specific information flow of crude oil prices is very important to understand the dynamics of world crude market, especially for countries like India and china it is very important because both the countries are emerging nations and dependent more on oil producing countries. About 80% of oil requirements of China are met by importing oil from Middle East and Africa. India too is dependent on Middle East for its 70% of oil requirements. As per the latest statistics of EIA, China's oil consumption in total energy is stood at 20% and of India it is 31%, China is slowly reducing its dependency on imports of crude oil thus making it as a significant player in world crude oil market. A study done by K.C.Chen et al (2009) has revealed that although china emerges to be an important player it has little impact on the volatility of the world crude oil markets.

This paper is aimed at understanding the causal relationships of oil markets among the selected OPEC and Non OPEC countries, the selection of countries is based on the capacity of production and consumption of oil and higher influence on price mechanism, their effect on the other developing nation like India and china. This study has taken a total of twelve countries, chosen in the study are major oil producers like Saudi Arabia, Iran, Iraq, Kuwait Nigeria, and Venezuela which are the OPEC countries representing middle east, North Africa and South America and Non OPEC countries US, Canada and Mexico representing North America, Malaysia and China representing Asia.

In this study India (not included in dataset) act as a watchdog of flow of price causal relations between the significant players of world oil market, but China is included in the dataset because of its recognizable impact on world oil market as a second largest consumer after US. Presently India is still more dependent on oil imports. This study will helpful for India to look at the price movement between the markets and continue make strategic alliance and relations with these countries in joint operations of oil exploration and production. The purpose of including Nigeria and Malaysia in the dataset is about 15% of oil imports of India are made by these two countries, to know the possible causal linkage of these countries with the other countries so that for India a possible alliance can be made to exploit the opportunities in world oil markets.

II. RESEARCH QUESTIONS

The purpose of this study is twofold one it gives an understanding of whether or not the selected OPEC and Non OPEC oil markets are integrated, if so what is the possible causal price relation running from each other markets, that is to determine the price movement from one market to the other market. Second it gives possible opportunities to explore for country like India to have strategic alliances with those which are causing price variations to developing nation like china, in other words India should move along the path of China to have strategic alliances with the other nations in exploration and production of oil.

This study uses both causal (empirical) and descriptive research to find the answers to some of the questions:

- In a group of top oil producing and consuming nations what price causal relations one would to expect so that an oil dependent country can make strategic alliances with the nations causing price variations.
- What would be the role of China and US as the world top consumers in a group of oil dominant countries?

III. DATA & METHODOLOGY

This study covers the period 1999 to 2010 of weekly price time series data (2000/01/29-2015/05/14) of selected countries of OPEC & Non OPEC countries taken from the EIA website published and authorized by Energy International Agency, USA. This time series data is analysed by using the econometric techniques namely Johansen's rank procedure to test whether the selected international oil markets are cointegrated or not, further VAR methodology is used to find the direction of causality and finally the same causal relationships are supported by applying causal data analysis TETRAD- IV software through Directed Acyclic Graph.

IJERMS
International Journal of Engineering Researches and Management Studies

3.1 Non Stationary & Cointegration

All the data variables in log level form and first difference of the log level variables are tested for stationary by using ADF (Unit Root Hypothesis) and KPSS statistics. All the data variables are converted into their log form to eliminate the scale effects and for the possible heteroskedasticity impact. The non stationary acts as a pre condition for the cointegration, therefore the dataset is tested for cointegration for possible long run relationships. If all the data variables in log form in the study have unit roots (non stationary) that is, they are integrated of order one, the next step is to determine whether or not there exists at least one linear combination of the non-stationary variables (in level form). Thus the next step is to see whether these variables are co integrated or not, that is whether selected markets crude price have long term or equilibrium relationship between them or not. Two or more variables in the study are said to be co-integrated if each of the series are themselves non-stationary, but a linear combination of them is stationary (Engle and Granger, 1987). The stationary linear combination is called the co-integrating equation and may be regarded as a long- run equilibrium relationship among the variables. The purpose of the cointegration test is to determine whether a set of non-stationary series is co-integrated or not.

In addition to the Engle-Granger causality technique, Johansen (1979) procedure of co-integration is also employed. Johansen's approach begins with an unrestricted VAR involving potentially non-stationary variables, which allows us to deal with models having several endogenous variables. A key aspect of Johansen's approach is isolating and identifying the "r" co-integrating combinations among a set of "k" integrated variables and incorporate them into an empirical model. The co-integration rank divides the data into r relations, towards which the process is adjusting (equilibrium errors), and k - r (k, number of non-stationary I(1) variables) relations, which are pushing the process (common driving trends).

3.2 Vector Auto Regression (VAR)

The VAR approach sidesteps the need for structural modeling by treating every variable as endogenous in the system as a function of the lagged values of all endogenous variables in the system. The term autoregressive is due to the appearance of the lagged values of the dependent variable on the right-hand side and the term vector is due to the fact that a vector of two (or more) variables is included in the system model. Since there are only lagged values of the endogenous variables appearing on the right-hand side of the equations, simultaneity is not an issue and OLS yields consistent estimates. Moreover, even though the innovations may be contemporaneously correlated, OLS is efficient and equivalent to GLS since all equations have identical regressors.

3.3 Directed Acyclic Graph

The causal relationships are tested by TETRAD IV causal analysis software introduced by Scheines, Spirtes, Glymour, and Meek (1994) for constructing the Directed Acyclic Graphs. The TETRAD IV analysis software, which incorporates the PC-algorithm which is designed to search for causal explanations of observational or mixed observational and experimental data in which it may be assumed that the true causal hypothesis is acyclic (DAG) and there is no hidden common cause between any two variables in the dataset. This output generates a Directed Acyclic Graph (DAG) that shows the direction of casual relationship among the tested variables.

IV. EMPIRICAL ANALYSIS

All the price variables are found to be non stationary in the level form, but all are integrated of order one. The ADF & KPSS test statistics used for testing the non stationarity of time series. The non stationary acts as a pre condition for the cointegration, therefore the dataset is tested for cointegration for possible long run relationships. Johansen's rank test for testing cointegration is useful whenever the dataset contains more than two endogenous variables. In this procedure after selecting the suitable lag length by using the appropriate criterion like AIC = Akaike criterion, BIC = Schwartz Bayesian criterion and HQC = Hannan-Quinn criterion we test for cointegration by using Trace test and LMax test (Maximum Eigen value) that confirms whether the price variables are cointegrated or not. After confirming the cointegration we use VAR calculations to determine the direction of causality, The VAR approach sidesteps the need for structural modeling by treating every variable as endogenous in

International Journal of Engineering Researches and Management Studies

the system as a function of the lagged values of all endogenous variables in the system. Finally the causal relationships are tested by TETRAD IV causal analysis software introduced by Scheines, Spirtes, Glymour, and Meek (1994) for constructing the Directed Acyclic Graphs.

4.1 Tests for Non Stationary

The data variables in log level form tested for non stationarity. The time series graph in level form clearly shows mixed trend with high volatility and fluctuations specially the rise in crude prices in the year 2008. The plot of differenced time series graph also show the possible co-integration among the oil markets. After testing for non stationary using Augmented Dickey Fuller (ADF) test and KPSS statistics where KPSS (Kwiatkowski, Phillips, Schmidt and Shin, 1992) is a unit root test in which the hypothesis is opposite to that in the ADF test: under the null, the series in question is stationary; the alternative is that the series I (1). If the calculated KPSS is greater than the critical value at the given level of significance then we reject the null hypothesis. All the price variables are found to be non stationary in the level form, but all are integrated of order one.

4.2 Co-integration of Oil Markets

Having found that all the variables in the study have unit roots that is, they are integrated of order one, our next step is to determine whether the price variables are co integrated or not, that is whether OPEC and Non OPEC have long term or equilibrium relationship between them or not. The time series graph of differenced variables shows expected co integration among the variables. Johansen's procedure of multivariate co-integration requires the existence of a sufficient number of time lags. To determine the lag length we used the standard information criteria, AIC = Akaike criterion, BIC = Schwartz Bayesian criterion and HQC = Hannan-Quinn criterion. For our data AIC criteria gives lag order three is chosen for testing cointegration. The selection of lag length results are given in table 2

International Journal of Engineering Researches and Management Studies

Table- 2 Selection of Lag Length

Lags	loglik	p(LR)	AIC	BIC	HQC
1	16337.78069		-57.078591	-55.884419	-56.612553
2	16843.93024	0.00000	-58.356015	-56.059529*	-57.459787
3	17123.33662	0.00000	-58.833639*	-55.434839	57.507221*
4	17250.67487	0.00000	-58.774867	-54.273754	-57.018260
5	17377.76104	0.00000	-58.715206	-53.111780	-56.528410
6	17494.54434	0.00000	-58.619204	-51.913464	-56.002218
7	17624.65768	0.00000	-58.570221	-50.762167	-55.523046
8	17774.75126	0.00000	-58.591715	-49.681348	-55.114351
9	17893.16320	0.00000	-58.501457	-48.488777	-54.593904
10	18029.09049	0.00000	-58.472982	-47.357988	-54.135239
11	18137.78506	0.00008	-58.348448	-46.131141	-53.580515
12	18240.94514	0.00051	-58.204392	-44.884771	-53.006270
13	18394.63309	0.00000	-58.238565	-43.816630	-52.610253
14	18532.46887	0.00000	-58.216821	-42.692573	-52.158320
15	18662.64038	0.00000	-58.168044	-41.541482	-51.679353
16	18774.60784	0.00002	-58.055054	-40.326179	-51.136174
17	18924.19402	0.00000	-58.074758	-39.243570	-50.725689
18	19071.76139	0.00000	-58.087342	-38.153840	-50.308083
19	19251.34039	0.00000	-58.212841	-37.177025	-50.003393
20	19420.76146	0.00000	-58.302510	-36.164381	-49.662872
21	19561.68054	0.00000	-58.291642	-35.051200	-49.221815
22	19732.51163	0.00000	-58.386284	-34.043529	-48.886268
23	19922.86363	0.00000	-58.549784	-33.104714	-48.619578
24	20096.07078	0.00000	-58.652807	-32.105424	-48.292412
25	20243.45947	0.00000	-58.664760	-31.015064	-47.874175
26	20431.27216	0.00000	-58.819302	-30.067292	-47.598528

The following table gives the results of Johansen's co-integration test. Both the Johansen trace tests and maximum eigenvalues support the rejection of the null hypothesis that there are no co-integrating relations in the system. From the results of the co-integration rank tests, we conclude that the trace and max eigenvalue tests both indicate more than one co-integrating equation. Indeed, we could find support from the economic theory for long-run relations among the selected oil markets. This relationship is important in explaining the variables of the model that requires the examination of the α and β vectors. The vector α is the vector of adjustment coefficients and vector β represents long term or co integrating coefficients.

From the economic theory, the hypothesis is that price causal relations between the significant players of world oil market contributes in discovering price mechanism between the member countries and also paves way for strategic alliance with the other countries depending upon the market structure, exploration and production opportunities . Evidence of co-integration between oil markets suggest that the country which causing price variations (cause) to other markets have major role to play in significantly controlling the price of oil. The direction of causality determines the order of the world oil markets.

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International Journal of Engineering Researches and Management Studies

Co-integration Test (Johansen approach)

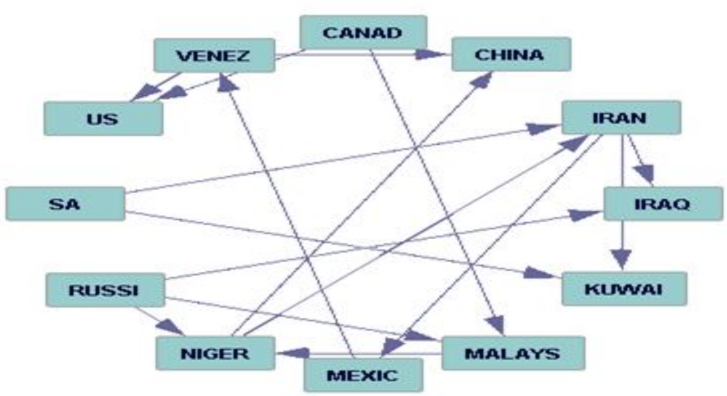
A. Co-integration rank Tests

Unrestricted co-integration rank tests, Trace & Maximum Eigen (Lmax) value

No.of co integrating Equations or Rank	Eigenvalues (λ_i)	Trace Test P-value	Lmax Test P-value
0	0.28906	922.45 [0.0000]	201.29 [0.0000]
1	0.25494	721.17 [0.0000]	173.63 [0.0000]
2	0.19667	547.54 [0.0000]	129.20 [0.0000]
3	0.16212	418.34 [0.0000]	104.36 [0.0000]
4	0.14226	313.98 [0.0000]	90.535 [0.0000]
5	0.11242	223.44 [0.0000]	70.359 [0.0000]
6	0.091082	153.08 [0.0000]	56.345 [0.0001]
7	0.053330	96.738 [0.0001]	32.335 [0.0729]
8	0.047396	64.403 [0.0005]	28.648 [0.0330]
9	0.031090	35.754 [0.0084]	18.634 [0.1099]
10	0.018895	17.120 [0.0265]	11.255 [0.1433]
11	0.0098914	5.8650 [0.0154]	5.8650 [0.0154]

*Both the Trace test and Lmax test indicates Eight co-integrating equations (Rank 8) at 5% level.

4.3 Direction of Causalty



Vector Auto Regression (VAR) model is used to determine the direction of causality running in between oil markets.Finally the causal relationships are tested by TETRAD IV causal analysis software which incorporates the

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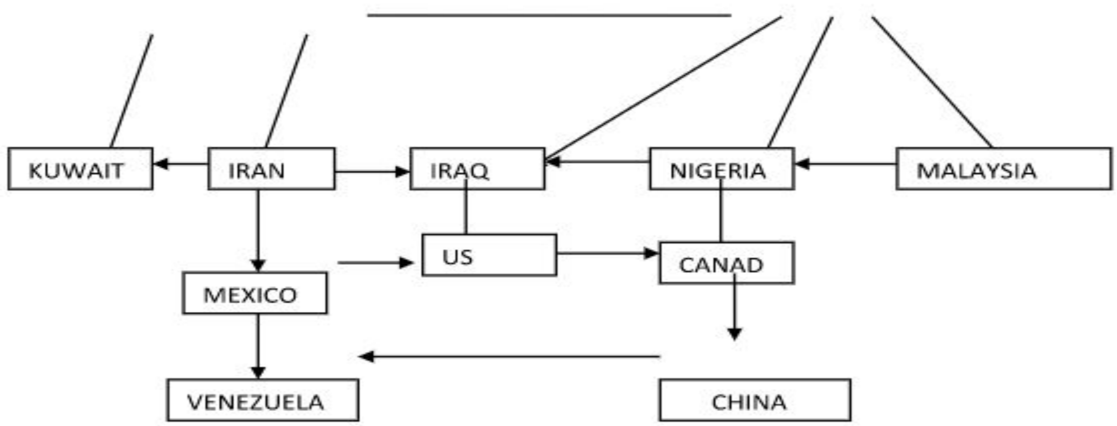
PC-algorithm which is designed to search for causal explanations of observational or mixed observational and experimental data in which it may be assumed that the true causal hypothesis is acyclic (DAG) and there is no hidden common cause between any two variables in the dataset. The output of Directed Acyclic Graph (DAG) that shows the direction of casual relationship among the tested variables is given below



V. OPEC & NON OPEC

The bi-directional causality is clear between the OPEC member countries and between OPEC and Non OPEC member countries showing their impact on the world oil market. In OPEC, Saudi Arabia is the dominant player in controlling the price mechanism along with Iran. The US market still has its control on world oil market by strategic alliances in terms ruling the dollar currency, especially with the nations Mexico, Iran and Saudi Arabia. It is observed that though China acts as a price taker it is slowly making his position by significantly improving the strategic alliances in exploration and production opportunities. The causal relationship from China to Venezuela is shows this fact in this direction.

VI. CONCLUSION

In this econometric study of updated time series data on crude oil prices taken from a total of twelve countries, Saudi Arabia, Iran, Iraq, Kuwait Nigeria, and Venezuela which are the OPEC countries representing middle east, North Africa and South America and Non OPEC countries US, Canada and Mexico representing North America, Malaysia and China representing Asia.

All the data variables are non stationary in level form and are integrated of order one, ADF tests concludes the stationary after first differencing and the dataset is tested for possible cointegration. The selection of lag length based on AIC criterion is selected as 3 and Johansen's rank test by using the Lmax and Trace test found the rank as 8 that confirms the cointegration which implies that the selected international oil markets are integrated. Further the VAR results showed the direction of causality and the same is confirmed by the TETRAD software DAG graph.

From the Directed Acyclic Graphs the flow of casual relations are very much clear between the selected OPEC countries where as there is no much price casual movement between the non OPEC member countries. This study reiterates the position of China in world oil markets, and it is observed that though China acts as a price taker it is slowly making his position by significantly improving the strategic alliances in exploration and production opportunities. The causal relationship from China to Venezuela is shows this fact in this direction.

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International Journal of Engineering Researches and Management Studies

Assuming the Ceteris Paribus a developing country like India can also join hands with the countries in the path of China. The recent accord between India and Venezuela in exploration and production of oil and gas is a welcome step in this direction. In this study the subjective selection of OPEC & Non OPEC countries can accommodate a true picture of causal relationships in a group of oil dominant countries.

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