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An econometric approach to analyse the perceived cartel behaviour of OPEC

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Abstract. *This paper is driven by the importance of OPEC and the mixed literature about its behaviour. The aim is to understand the debated structure of OPEC and determine using econometric tools and applying market sharing models whether the organization behaves like a cartel or is wrongly accused of being so using the annual data for 2004-2019 period. Application of Herfindahl-Hirschman Index shows a shift in its behaviour from competitive to moderately concentrated marketplace from 2013. Crude oil output coordination of member nations with OPEC is established using cointegration test. Besides this, Granger causality test suggests that Iraq's crude oil production causes price of oil which is further confirmed by applying market share model where Iraq acts as a price setter.*

Keywords: OPEC, oil production, cartel, cointegration, causality.

JEL Classification: C22, L11, Q40.

1. Introduction

The Organization of the Petroleum Exporting Countries (OPEC) is an intergovernmental organization, created at the Baghdad Conference in September 1960 by Iran, Iraq, Kuwait, Saudi Arabia and Venezuela (called the five founders). Its formation was based on the distribution of world petroleum reserves. The Baghdad conference was called to ensure that the oil prices should not fall (given its persistent oversupply) and to accomplish this, the founding members stood united. The organization is now a group consisting of 13 of the world's major oil-exporting nations. These are: Algeria, Angola, Congo, Equatorial Guinea, Gabon, Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, UAE and Venezuela. According to the OPEC Annual Statistical Bulletin 2019, 79.4 per cent of the world's accessible oil reserves are located in OPEC member countries. This makes it one amongst the most important organizations in the world. Venezuela has highest oil reserves and Equatorial Guinea lowest among OPEC countries. OPEC is generally considered a cartel. The spike in oil prices during early 1970s was attributed to collusive behaviour of OPEC. After 1982, OPEC adopted the policy of fixing output quota of member countries but continued policy of announcing oil price as well, but oil price keeps on fluctuating. Thus, OPEC was not successful in keeping the oil prices stable in 1980s which sparked the debate of OPEC being a questionable cartel.

OPEC faces two main problems. To begin with, member nations generally overestimate their reserves to hold a greater quota. Second, monitoring of quotas is a difficult task since oil production is hard to trace and check, members can easily produce more than the established quotas. OPEC enforces price control by rationing the amount of crude oil to the world. This leads to incentives for member countries under economic strain and market crisis to produce more than established quotas and enjoy higher profits. Thus, deviation of any country from its quota mandate to reap more in short-run will forsake the collusive approach and severely adversely affect the long-term gains of the organization.

There has been a considerable curiosity and concern over OPEC behaviour and its role in the international oil market. Various contradictory hypotheses have been formulated about OPEC behaviour from different points of views. Analysts have been puzzled over OPEC's role in determining world's oil price. The economists in the West see OPEC as a cartel, while Arab scholars commonly argue that prices of oil remain competitive. This paper is thus driven by the importance of this organization and the mixed literature about its unsaid behaviour.

The remainder of this paper is divided into four sections. Section 2 gives a brief review of literature. Section 3 describes data and methodology used in the study. Section 4 presents empirical results about the testing of alternative hypotheses related to OPEC behaviour. The last section presents conclusion.

2. Literature review

Various researchers and scholars have worked on the ever-expanding literature on behaviour of OPEC. Some view the organization as a cartel which has a significant role in determining world oil prices and achieving its targets or objectives while others have rejected the theory and proved against this conceptional behaviour. A brief review of some existing literature is discussed below.

Griffin (1985) tested the various alternative theories to explain OPEC behaviour using quarterly data for the time period 1971:1 to 1983:3. The models empirically tested were competitive model, market sharing variant of cartel, property rights model and target revenue model. Among OPEC countries, none member rejected partial market sharing cartel model and frequent rejections were observed for other theories. In terms of the ability of various models to explain production, the partial market sharing cartel model dominated the competitive model. However, the competitive model could not be rejected for 10 of 11 non-OPEC countries. Ramcharran (2002) investigated the competitive model to ascertain production behaviour and used a supply function based on modification of Griffin's model for the time period 1973-1997. The OPEC results do not support the competitive hypothesis and offer partial support for the target revenue theory. For most of the non-OPEC members, the author's results support competitive market model. Dahl and Yucel (1989) built a model on OPEC behaviour which would be consistent with dynamic optimization. The authors used quarterly data from 1971:1 to 1986:4. They arrived at the conclusion that countries did not behave like a strict cartel but there is evidence of non-competitive behaviour for Algeria, Kuwait, Nigeria, Saudi Arabia and Venezuela. Colgan (2014) investigated the working of OPEC that gives the impression of having a significant influence over the market for petroleum. The author's empirical results using event history approach and regression analysis for the time period 1982-2009 concluded that OPEC has little or no impact on its members' production levels.

Gülen (1996) aimed to confirm if the organization behaved as a cartel, nations stick to their quota system and if OPEC has the authority of controlling the oil price by controlling crude output levels. The author used cointegration and causality tests and confirmed that OPEC acted like a cartel in 1980s to maintain the prices but not earlier than that. Kaufmann et al. (2004) captured the relationship between real oil prices and OPEC behaviour using tests of cointegration and causality on quarterly data of OPEC from 1986:3 through 2000:3. The results confirm that quotas, among many other variables unidirectionally (Granger) cause oil prices. Simpson (2004) concluded that OPEC market prices Granger cause world market prices and USA Market price and there is no significant causality from either world or USA prices to OPEC prices. Reynolds and Pippenger (2010) conducted a Granger causality test to understand the causal direction between oil production and quota for Venezuela. Their study concludes that in the short-term, Venezuela's quota (Granger) causes oil production of Venezuela and in the long run, oil production of Venezuela unidirectionally (Granger) causes quota. Thus, organization does not command oil output but reacts to it. Bremond et al. (2012) tested production decisions of the member countries and influence on oil prices relying on cointegration and causality tests in time series and panel settings using monthly data from 1973 to 2009 and concluded that OPEC is a price taker for sub periods in the analysis.

Alhajji and Huettner (2000) aimed to investigate the existence of a dominant producer in the world crude oil markets using simultaneous-equation model to test the competitive, Cournot and dominant firm models for the oil markets for the period 1973-1994 (using quarterly data). They conclude that OPEC does not fit dominant firm model. Saudi Arabia acts as dominant producer hence world oil market is dominated by the latter not OPEC and there was no statistical support for Cournot or competitive model. Yang (2004) aimed to

understand the dynamics of production behaviour of OPEC and its impact on world oil market using quarterly data for time period 1984-2000 by fitting a market sharing model using regression and then Markov regime switching model. It was concluded that organization operated as a market sharing cartel since 1980s with Saudi Arabia as the leader. Hansen and Lindholt (2008) tested if the behaviour of OPEC can be regarded as dominant producers of world crude market using simultaneous-equation econometric model taking monthly data from 1973 to 2001 and found that group of producers outside OPEC can be described as competitive producers, maximizing profits and taking price of oil as given but OPEC members cannot be considered as price takers. Almoguera et al. (2011) aimed to test for switches in OPEC behaviour and explore which market structure fits best during period of analysis using simultaneous equations switching regression model and extension of Porter's setup. Results suggest spells of collusive behaviour in early 80s. Despite that, OPEC cannot be viewed as an effective cartel during 1974-2000 period but as a non-cooperative oligopoly. Lawell (2013) used the Hotelling model and regression analysis for the period from 1970 to 2004 to test if OPEC countries colluded and whether non-OPEC countries behaved as oligopolists. Result of the analysis by decade indicate that OPEC countries collude as the dominant cartel producer and non-OPEC countries behave as oligopolistic fringe. Rousan et al. (2018) examined how the integration level of oil producing nations changed during the period 1996-2016 by constructing a dynamic network structure for 13 OPEC member countries and 17 non-OPEC countries and reported significant changes. OPEC's influence has waned, while non-OPEC has grown. Kheiravar et al. (2020) analysed the effects of hypothetical change in OPEC membership on the petroleum industry using structural econometric model of dynamic games for the time period 2000-2005 and showed that OPEC behaves in a way that is consistent with its mission to increase average firm payoff to its members and cartel behaviour of decreasing oil production to increasing oil price.

Smith (2005) tested the conduct of members of the organization from 1973 through 2001 using tests of compensating behaviour and concluded growing consensus of cohesiveness among member nations. It is also concluded that after the introduction of formal quota mechanism in 1982, the transaction costs within the organization increased.

Boug et al. (2016) aimed to analyse OPEC's behaviour from 1992 to 2015 applying cointegration analysis. They found evidence for imperfect competition hypothesis in regards to production choice of OPEC and price elasticity of demand for OPEC oil consistent with dominant producer model. Golombek et al. (2018) estimated a dominant firm-competitive fringe model for OPEC member countries and the group of non-OPEC producer countries using the quarterly data of oil prices from 1986 to 2016 and estimated significant elasticities. They confirmed the dominant firm-competitive fringe model. To assess the market power of OPEC, Lerner Index was calculated.

The various authors who contributed to literature on the behaviour of OPEC members and as a group have mostly worked with weekly, monthly and quarterly data sets. Here, seasonal fluctuations may affect the results and thus this paper aims to study the cartel behaviour using annual data. Another limitation is of lack of availability of literature on market sharing models. Dominant firm and competitive fringe model have been studies

extensively and some notable work has been done using game theory, Cournot equilibrium and Stackelberg Model. The literature on market sharing model is yet to be explored. Cost based analysis and use of Lerner index has been seen in various papers, but this paper deviates from this approach and takes help of Herfindahl-Hirschman Index to measure the degree of competitiveness without making any assumption regarding the production costs.

This paper aims to understand the debated structure of OPEC and tries on determining using econometric tools and also by applying market sharing models whether the organization behaves like a cartel or is wrongly accused of being so.

Following are the objectives of the paper:
- To measure the degree of competitiveness of OPEC over the period under study.
- To test if production behaviour of different countries belonging to OPEC are coordinated.
- To test if production by OPEC members influences the oil prices.
- To fit the market sharing models for all OPEC members.

3. Data and methodology

The annual report of OPEC is taken as the major source of obtaining data for the production of oil by OPEC as a group and of individual member nations. It is also the source for obtaining the crude oil reserves of its members. The annual price of oil per barrel in USD is taken from the mentioned report as well. The real price of oil is derived by deflating the nominal price of oil at constant 2010 USD prices as per U.S. Bureau of Labor Statistics. The period of analysis is 16 years from 2004 to 2019.

Tools and tests

3.1. Herfindahl-Hirschman Index

The Herfindahl-Hirschman Index (HHI) is a statistical measure to understand the degree of concentration. It is independently developed by American economist Orris C. Herfindahl (1950) and German economist Albert O. Hirschman (1945). It has achieved its visibility for a statistical index because of its use by the U.S. Department of Justice in the analysis of the competitive effects of mergers. Due to the importance attached to market concentration as an indicator of competition and the relative ease of calculation, this index serves as an efficient screening mechanism.

By including the relative size (i.e., market share) of all the participants in the industry, the HHI reports for the number of producers in the market and also the concentration. It is computed by squaring all of the firms' market share and then totalling the squares.

$HHI = S_1^2 + S_2^2 + \ldots + S_n^2$

Where:
n – no. of members in the organization.
S_i – market share of i^{th} member (in %), i = 1, 2,…, n.

When there are a large number of enterprises of similar size in a market its value approaches zero and when there is only a single enterprise in a market its value reaches a maximum of 10,000 points. Thus, higher values of the HHI are indicative of higher market concentration and monopoly power or decreased competitiveness. The U.S. Justice Department has proposed numerical guidelines which are also used by the Federal Reserve. For a value of HHI<1500, the marketplace is concluded as competitive; for a range of 1500-2500, the marketplace is moderately concentrated and HHI of more than 2,500 is indicative of highly concentrated marketplace.

3.2. Cointegration test and error correction mechanism

If OPEC is capable of working as a cartel that synchronized production of its member countries, total output will be based according to their quota mandate. In that situation, one would expect a member country's oil production and rest of the OPEC oil production (calculated by subtracting individual member production from total OPEC production) to move together, at least in the long-run. This would show long-run equilibrium relationship between a country's oil output and rest of OPEC oil output level. In terminology of time series, it is called that these two series should be cointegrated. The absence of cointegration between a country's oil output level and that of rest of the organization oil output level could indicate poor cooperation between the members and OPEC and the ineffectiveness of the cartel.

Granger (1981) and Engle and Granger (1987) introduced the concept of cointegration. Cointegrating equation retains the terms in levels but only in linear combinations that are stationary. The Granger theorem states that if both Y_t and X_t are I(1), then the linear combination of them is I(0) or stationary. Here, the regression will not be spurious. Before proceeding to the cointegration analysis, each variable, i.e., individual production of crude oil by OPEC member nations and rest of the group crude oil production are tested for stationarity using ADF test.

Engle and Granger (1987) provided a test to examine the presence of cointegrating relationship (i.e., long-run relationship) between the variables. For this, ADF test is applied on the variables and if both the variables are I(1), we generate a series of residuals $e_t = Y_t - \hat{Y}_t$ where $\hat{Y}_t = \hat{a} + \hat{b}X_t$ is the integrating equation which shows long-run relationship between the variables. The stationarity of residuals is checked to see if the variables are actually integrated. Model: $\Delta e_t = \delta e_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta e_{t-i} + v_t$

H_N: $\delta = 0$

The null hypothesis is of no cointegration. If the null hypothesis is rejected, our conclusion is that residuals are stationary and variables are cointegrated.

The cointegrating equation $\hat{Y}_t = \hat{a} + \hat{b}X_t$ gives long-run relationship and does not shed any light on the short-run dynamics. It is thus necessary to construct a more comprehensive model which combines the short-term along with the long-term dynamics. This is done by the Error Correction Mechanism (ECM). We can write the ECM as

$\Delta Y_t = \phi + \gamma \Delta X_t + \lambda e_{t-1} + w_t$

e_{t-1} is one period lagged value of error term from cointegrating equation.

In the ECM stability condition will be as follows: If λ is negative and statistically significantly different from zero, then short-run disequilibrium can be corrected and long-run stable equilibrium can be achieved, otherwise not. If λ> 0 and significant, the model shows unstable equilibrium.

3.3. Causality test

The main objective of forming a cartel is to push oil price higher than it would be under competitive market conditions. OPEC is often accused of curbing oil production so that it can raise oil price. If OPEC is able to raise oil price by reducing oil output it can be tested by causality test. In that situation there should be causality from oil output to oil price and not from oil price to oil output.

Granger (1969) offered for the first time a formal test of direction of causality between the variables. It is basically a statistical test. If OPEC has really influenced the market price of oil, there should be unidirectional causality from the organization's oil production to the oil price, not in other direction, i.e., Q (production) (Granger) causes P (price). The test will be based on null hypothesis of no causation.

To test the causation, following equations are to be estimated:

$$Q_t = a_1 + \sum_{i=1}^{n} \alpha_i (P)_{t-i} + \sum_{j=1}^{m} \beta_j (Q)_{t-j} + \varepsilon_{1t}$$

$$P_t = a_2 + \sum_{i=1}^{n} \gamma_i (P)_{t-i} + \sum_{j=1}^{m} \delta_j (Q)_{t-j} + \varepsilon_{2t}$$

Where:
Q_t – Crude oil production.
P_t – Price of oil, and
ε_{1t} and ε_{2t} are white noise error terms.

The above first equation implies that production at time t depends on past values of itself and that of price of oil and the second equation represents that price of oil at time t depends upon past values of itself and that of OPEC oil production.

Here arise following four situations:

1. If the estimated values of $\alpha_i s$ are statistically significantly different from zero and estimated values of $\delta_j s$ are not statistically significantly different from zero, there exists unidirectional causality from price to production and we say P (Granger) causes Q.
2. If the estimated values of $\alpha_i s$ are not statistically significantly different from zero and estimated values of $\delta_j s$ are statistically significantly different from zero, there exists unidirectional causality from production to price and we say Q (Granger) causes P.
3. If all coefficients are statistically significantly different from zero, there exists bidirectional or feedback causality.
4. If all coefficients are not statistically significantly different from zero, both variables are independent.

3.4. Market sharing model

Griffin (1985) concluded that OPEC members acted as market-sharing cartel for the period 1971 through 1983. In 1982, OPEC started quota system to manage output among its members and subsequently admitted that it was designed to maintain market position. This model thus resembles reality and does not include concepts of production or user costs for which neither data is well available nor are their reliable proxies. Griffin's empirical model can help in examination of how the individual OPEC members perform in this form of collusion.

The log-linear form of the model is specified as follows:

$\ln Q_t = \alpha + \gamma \ln P_t + \beta \ln Q_t^{oo} + \varepsilon_t$

Where:
Q_t – Production of an individual OPEC member.
P_t – Price of oil, and
Q_t^{oo} – Other OPEC members' production.

Three tests were performed by Griffin: Constant market sharing ($\beta = 1$ and $\gamma = 0$) shows market share among member nations is not altered by price of oil, market sharing ($\beta = 1$and $\gamma \neq 0$) represents market share changes according to oil price and partial market sharing ($\beta \neq 0$ and $\gamma \neq 0$) advocates loose cartel since market considerations partially affect the output choices and the members may also adjust their production levels with price.

The regression model is fitted for each OPEC member and if values of β and γ are found significant at given level of significance, the signs of the coefficients guide in decision making.

4. Empirical results

4.1. OPEC behaviour: View from degree of competitiveness

The market share for the OPEC members is calculated on the basis of crude oil production in thousands of barrels per day from 2004 to 2019. Individual member's market share is calculated by dividing the member nation's crude oil production (1000 barrels per day) with that of total OPEC production for each year. The market share is expressed as a per cent and is squared for further calculation of the index. The squared value is summed for calculation of the HHI score. Table 1 shows the HHI scores for the period of analysis.

Table 1. *Annual HHI scores for OPEC*

Year	HHI
2004	1471.39
2005	1474.30
2006	1431.30
2007	1377.03
2008	1396.97
2009	1352.81
2010	1356.67
2011	1519.54
2012	1487.40

Year	HHI
2013	1522.32
2014	1567.52
2015	1657.67
2016	1680.22
2017	1616.95
2018	1682.39
2019	1718.34

Source: Authors' calculation.

The HHI score of less than 1500 for the year 2004 through 2012 (except 2011) is indicative of competitive market. For the year 2013 and onwards the scores range from 1522.32 to 1718.34, which show a moderately concentrated marketplace. Thus, it can be concluded that for the period of analysis, OPEC has changed its nature from competitive marketplace to moderately concentrated marketplace with a tendency of increase in HHI scores annually.

4.2. OPEC behaviour: Test of production coordination

For the full period under analysis, the data is available for 10 OPEC members namely Algeria, Angola, Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, UAE and Venezuela. The results indicate that log form production series for Algeria, Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia and UAE are stationary at their first difference around a constant using ADF test. Results do not reject null hypothesis of unit root for 2 OPEC members namely, Angola and Venezuela.

Table 2 summarizes the results.

Table 2. *ADF test of stationarity of production series of OPEC members*

Country	ADF Test at Level		ADF Test at First Difference	
	τ-statistic	p-value	τ-statistic	p-value
Algeria	0.262012	0.9672	-3.109849*	0.0529
Angola	-1.972012	0.2940	-2.318871	0.1797
Iran	-1.706686	0.4068	-3.887102**	0.0163
Iraq	0.009555	0.9431	-3.745956**	0.0171
Kuwait	-1.751046	0.3879	-3.364468**	0.0314
Libya	-1.960659	0.2988	-4.889687***	0.0021
Nigeria	-1.525959	0.4936	-3.479849**	0.0256
Saudi Arabia	-1.532944	0.4902	-4.024064***	0.0097
UAE	-0.560621	0.8523	-3.414017**	0.0288
Venezuela	9.297285	1.0000	2.829579	0.9999

* Significant at 10 per cent level.
** Significant at 5 per cent level.
*** Significant at 1 per cent level.
Source: Authors' calculation.

Since I (1) is a precondition for cointegration test, the production series for Angola and Venezuela are excluded from the analysis for the period under consideration. The study is, thus, conducted for 8 OPEC members. These countries are: Algeria, Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia and UAE. After conducting unit root test of log form production series for OPEC members, unit test was conducted for log form series of rest of the OPEC production related to these 8 countries.

The results are given in Table 3.

Table 3. *ADF test of stationarity of rest of the OPEC production series*

Country	ADF Test at Level		ADF Test at First Difference	
	τ-statistic	p-value	τ-statistic	p-value
OPEC-Algeria	0.262012	0.0980	-3.109849***	0.0087
OPEC-Iran	-2.449965	0.1459	-4.717518***	0.0029
OPEC-Iraq	-1.297220	0.6020	-3.275149**	0.0427
OPEC-Kuwait	-3.058575	0.0520	-4.149066***	0.0013
OPEC-Libya	-2.162765	0.2258	-3.512933**	0.0241
OPEC-Nigeria	-2.653036	0.1049	-3.857710**	0.0130
OPEC-Saudi Arabia	-2.396327	0.1588	-4.405473***	0.0073
OPEC-UAE	-3.185711	0.0415	-4.107192***	0.0083

** Significant at 5 per cent level.
*** Significant at 1 per cent level.
Source: Authors' calculation.

The results indicate that log form series of rest of the OPEC production related to Algeria, Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia and UAE are stationary at their first difference around a constant using ADF test.

After testing for stationarity cointegration test was conducted. The result of pairwise cointegration of individual OPEC member country's production with rest of the OPEC production is reported in Table 4. The null hypothesis of no cointegration is rejected for Algeria, Iraq, Libya and Nigeria at 5 per cent level of significance and for Iran and UAE at 10 per cent level of significance. However, for Kuwait and Saudi Arabia, the hypothesis of no cointegration cannot be rejected even at 10 per cent level of significance.

Table 4. *Test of cointegration for each OPEC member's production with rest of the OPEC production*

Country	t-statistic	p-value
Algeria	-3.183036**	0.0417
Iran	-2.878573*	0.0714
Iraq	-3.112046**	0.0473
Kuwait	-2.596029	0.1153
Libya	-3.266556**	0.0359
Nigeria	-3.181058**	0.0418
Saudi Arabia	-2.609834	0.1127
UAE	-3.081515*	0.0500

* Significant at 10 per cent level.
** Significant at 5 per cent level.
Source: Authors' calculation.

The results show that Algeria, Iran, Iraq, Libya, Nigeria and UAE are the countries which coordinate output with rest of the OPEC in the long-term although the findings are weak for Iran and UAE (significant at 10 per cent level). The countries which do not seem to coordinate output for the period under study are Kuwait and Saudi Arabia (the null hypothesis of no cointegration cannot be rejected even at 10 per cent level). Kuwait & Saudi Arabia are significant members of OPEC. These members seem uncooperative with total OPEC production. This may be on account of cheating by the members or the swing producer roles they seem to be associated with.

To allow for both short-run and long-run equilibrium, ECM is used on all OPEC members excluding Angola and Venezuela. The coefficient of one period lagged value of error term from cointegrating equation is checked for significance to conclude a stable relationship. Table 5 summarizes the results.

Table 5. *Test of ECM for stable equilibrium*

Country	Coefficient (λ)	p-value
Algeria	-0.695476**	0.0390
Iran	-0.718755**	0.0165
Iraq	-1.023167**	0.0108
Kuwait	-0.605908	0.1124
Libya	-0.983475***	0.0016
Nigeria	-1.075105***	0.0091
Saudi Arabia	-0.622652	0.1819
UAE	-1.001891**	0.0410

** Significant at 5 per cent level.
*** Significant at 1 per cent level.
Source: Authors' calculation.

ECM results show that Kuwait and Saudi Arabia do not seem to have a stable equilibrium, though their coefficients of λ are negative but not statistically significant. The results are quite satisfactory for Algeria, Iran, Iraq and UAE since their coefficient of λ are significant at 5 per cent level and highly satisfactory for Libya and Nigeria on account of being statistically significant at 1 per cent level of significance. It indicates that for these six members, if there were any short run disturbances from long run stable relationship (as seen in cointegration analysis), they would be corrected over time and the long run relationship would be restored. It is thus concluded that 6 out of 8 members seem to coordinate their individual crude oil production output with rest of the OPEC production.

4.3. OPEC behaviour: Test of price influence

The causal analysis is first carried out for production of OPEC with price. If the organization can influence oil prices (i.e., exercise cartel like behaviour), the null hypothesis of production does not (Granger) cause price should be rejected. If not, it is concluded that OPEC has no significant influence on oil prices and is wrongly accused of this cartel like behaviour. The variables are first checked for unit root. The result is shown in Table 6.

Table 6. *Test for unit root for OPEC production and price of oil*

Variable	τ-statistic	p-value
Production	-4.155489***	0.0076
Price	-3.180083**	0.0434

** Significant at 5 per cent level.
*** Significant at 1 per cent level.
Source: Authors' calculation.

The null hypothesis of unit root is rejected for both variables after transforming them in log form and then taking the first difference. After testing unit root pairwise Granger Causality test was applied. Result is given in Table 7.

Table 7. *Granger causality test for OPEC production and price of oil*

Organization	Price does not Granger cause production		Production does not Granger cause price	
	F-statistic	p-value	F-statistic	p-value
OPEC	0.63752	0.5535	0.89460	0.4460

Source: Authors' calculation.

For OPEC, the null hypothesis of production does not (Granger) cause price cannot be rejected and it is thus concluded that OPEC production does not influence market price of oil and thus does not show case of cartel like behaviour for the period of analysis.

The oil production of 8 individual OPEC members is also tested for causal relationship with oil prices and the result obtained is shown in Table 8.

Table 8. *Granger causality test for OPEC member's production and price of oil*

Country	Price does not Granger cause production		Production does not Granger cause price	
	F-Statistic	p-values	F-Statistic	p-values
Algeria	0.09469	0.9107	2.85445	0.1160
Iran	3.61143*	0.0763	0.74109	0.5067
Iraq	1.47099	0.3287	4.43337*	0.0713
Kuwait	0.0200	0.9957	1.22779	0.3912
Libya	0.07814	0.9255	0.68791	0.5301
Nigeria	0.18552	0.8341	0.04831	0.9531
Saudi Arabia	0.25209	0.7831	1.71123	0.2406
UAE	0.09045	0.9144	0.68918	0.5295

* Significant at 10 per cent level.
Source: Authors' calculation.

Table 8 shows that except for Iraq, the hypothesis of production does not (Granger) cause price cannot be rejected. However, Iran shows a unidirectional causality from price to production at 10 per cent level of significance. Algeria, Iraq and Saudi Arabia have comparatively much lower p-values (less than 0.25) from production to price whereas, most of the p-values for price to production are more than 0.75 (except for Iran and Iraq). It seems that OPEC crude oil production has not been able to significantly influence the market prices of oil from 2004 to 2019 but Iraq has affected the market prices.

4.4. OPEC behaviour: View from market sharing model

This section aims to study the market share cartel model for post-Griffin period of 16 years (2004-2019) and provide interpretations and grouping of members using the same. The study is also extended by comparing if the results are consistent with that of Griffin or OPEC has undergone some changes as an organization. The OLS method is used to carry the regression analysis for the period under study. The hypotheses tested are $\gamma = 0$, $\beta = 1$ and the interpretation and member grouping are thus made. Results displayed in Table 9 show that the price coefficient of none of the members is significant and coefficient of other members' production is insignificant for Kuwait, Saudi Arabia and UAE.

Table 9. *OLS Regression estimation*

Country	γ	β	R^2	LM-Statistic
Algeria	0.100666 (0.1993)	-0.832069** (0.0380)	0.213174	11.06816*** (0.0009)
Iran	-0.083209 (0.5039)	-1.949643** (0.0187)	0.208691	0.921207 (0.3372)
Iraq	-0.149098 (0.4860)	-5.135094*** (0.0034)	0.448651	6.671168*** (0.0098)
Kuwait	0.019364 (0.7207)	1.513724 (0.4427)	0.293413	11.24562*** (0.0008)
Libya	0.116720 (0.7462)	-9.282221*** (0.0045)	0.430753	0.958017 (0.3277)
Nigeria	0.083012 (0.3414)	-1.725187*** (0.0049)	0.326988	5.130427** (0.0235)

Country	γ	β	R^2	LM-Statistic
Saudi Arabia	-0.058913 (0.3393)	-0.125566 (0.1241)	0.076398	5.650421** (0.0175)
UAE	-0.079874 (0.3057)	0.927671 (0.9371)	0.151557	10.32890*** (0.0013)

Note: values within parentheses are p-values.
** Significant at 5 per cent level.
*** Significant at 1 per cent level.
Source: Authors' calculation.

These OLS estimates and thus the model for each OPEC member is unreliable due to presence of first order autocorrelation identified using Breusch-Godfrey Lagrange Multiplier Test. It is a powerful test based on null hypothesis of no autocorrelation. The validity of null hypothesis is tested on the basis of LM-statistic (given in Table 9) which follows a chi-square distribution. The decision is made using the respective p-values associated with the LM-statistic, i.e., if p-value is less than 0.05, the null hypothesis of no autocorrelation is rejected at 5% level of significance.

This situation is improved by estimating the model for each member by applying the iterative method. The new estimates are presented in the Table 10.

Table 10. *Output using iterative procedure*

Country	γ	β	AR(1)	Adj. R^2
Algeria	0.051443 (0.1261)	0.403992** (0.0234)	1.020774*** (0.0000)	0.907728
Iran	0.021633 (0.9199)	0.187557 (0.5515)	0.740396* (0.0622)	0.203013
Iraq	-0.158542** (0.0343)	0.609206 (0.4192)	0.999998*** (0.0000)	0.964920
Kuwait	0.043586 (0.3582)	0.992137 (0.9803)	0.883290*** (0.0005)	0.729635
Libya	0.337314 (0.5191)	-6.391819 (0.1378)	0.353353 (0.3567)	0.312418
Nigeria	0.163145** (0.0415)	-0.426197** (0.0146)	0.688736*** (0.0013)	0.710604
Saudi Arabia	0.039660 (0.5273)	0.697680 (0.5131)	0.869892*** (0.0008)	0.486276
UAE	0.024199 (0.6116)	0.579888 (0.2351)	0.999999*** (0.0000)	0.783420

Note: values within parentheses are p-values.
* Significant at 10 per cent level.
** Significant at 5 per cent level.
*** Significant at 1 per cent level.
Source: Authors' calculation.

Table 10 shows a significant negative price coefficient for Iraq and a significant positive coefficient for Nigeria. However, other members' production coefficients are significant only for Algeria and Nigeria. The summary of grouping members as per market sharing strategy is given in Table 11.

Table 11. *Summary of market sharing model*

Model	No. of members	Members
Market Sharing	6	Algeria, Iran, Libya, Saudi Arabia, UAE, Kuwait
Partial Market Sharing	1	Nigeria
Partial Market Sharing and Price Setting	1	Iraq

Source: Authors' calculation.

A prominent result from this analysis is that six out of eight OPEC members studied show an insignificant price coefficient. This property is indicative of effective coordination among these members. Nigeria has a significant positive price coefficient and only Iraq confirms a negative statistically significant price coefficient for the period of analysis. This is an important result as market share changing with price is an indication of deviation from coordination among OPEC members.

The result show that Iraq behaves as a price setter since only Iraq has a significant negative coefficient of price and the null hypothesis of $\gamma = 0$ is rejected. The negative coefficient guides in concluding that Iraq adjust its production inversely to price, an inconsistent behaviour of competitive producer. A negative significant other members' production coefficient for Nigeria indicates that it may act like a dominant producer.

Table 12 compares the results of Griffin (common members) with the results obtained from this study to see if OPEC has undergone behavioural changes.

Table 12. *Comparison of results with Griffin's study*

	This study (2004-2019)		**Griffin (1971-1983)**	
Country	γ	β	γ	β
Algeria	0.05	0.40	0.005	0.74
Iran	0.02	0.19	0.05	0.88
Iraq	-0.16	0.61	0.29	-0.06
Kuwait	0.04	0.99	-0.39	1.41
Libya	0.34	-6.39	-0.27	0.72
Nigeria	0.16	-0.43	0.10	1.13
Saudi Arabia	0.04	0.70	0.29	0.74
UAE	0.02	0.58	0.20	1.00

Source: Authors' calculation.

A prominent difference between the two studies is that two members (excluding uncommon members) had negative and statistically significant price coefficients for Griffin period whereas post-Griffin, only Iraq showed the same. This indicates an improvement in coordination among the member countries.

5. Conclusion

Since the inception of OPEC, various researchers have been fixated on the organization's influence and its role in the oil market. Researchers have formulated various hypotheses regarding the behaviour of the organization, majorly categorized into cartel and non-cartel models.

Within this context, the aim of this study is to investigate the perceived cartel behaviour of OPEC and that of member nations and determine if the organization performs like one by testing the market concentrations, production choices and price influence.

Firstly, OPEC's degree of competitiveness is checked using HHI which indicated a change in its nature from competitive marketplace to a moderately concentrated one for the period of study.

Secondly, cointegration analysis and ECM are used to assess the relationship between each nation's production or output and the rest of the organization's output. Most members seem to move in lockstep with the organization except for Kuwait and Saudi Arabia. Thus, evidence favours coordination among the member nations.

Thirdly, one would expect OPEC to influence market prices of its crude oil production due to its perceived cartel label. It has been accused of deliberately limiting its production to increase prices and therefore this causal relationship is examined using Granger causality test. For the whole time period, OPEC production does not Granger cause prices and vice-versa. Next, individual members of the organization are considered to see if they affect the market prices and Iraq's production seems to exert a significant influence on the market prices of oil.

Fourthly, to understand the collusion strategy of member countries, market sharing model is estimated and this study supports that OPEC has acted as a market sharing cartel for the period of analysis. Market sharing model could not be rejected for 6 out of 8 OPEC members under study. These 6 members are widely supportive of market share policy with insignificant coefficient of price and other members' production coefficient being unity. Nigeria has significant positive coefficient on price and negative coefficient on other members' production, therefore it follows a partial market share strategy. This may be due to its export destination to Atlantic basin where gulf crude becomes less attractive. Nigeria thus competes with non-OPEC crude oil. In 1980s, Nigeria was consistent with OPEC's price policy but with falling demand in Atlantic basin and increase in non-OPEC crude supply, Nigeria had a miserable experience with its steep fall in production levels and thus realized that its full support in price policy was not in the best individual interest. The estimation results show that Nigeria adjusts its production positively with price as opposed to other members of the organization. One prominent finding of this study is that only Iraq has a negative and significant price coefficient which strongly indicates that Iraq is a price-setter. Thus, Iraq takes the role of cartel leader to maintain stability and success of this organization. It is intriguing to understand the basis of Iraq's production decision.

Overall, the study is in favour of OPEC behaving as a cartel for the period of 2004-2019. Members of the organization coordinate crude output and Iraq acts as a cartel leader which sets the crude price.

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