



The role of quantitative methods in analyzing competition through quantities :A case study of OPEC and non-OPEC

Samir CHEKLELOU *	Mohammed BENMERIEM
s.cheklelou@univ-chlef.dz	m.benmeriem@univ-chlef.dz
The Euro-Mediterranean Research and Studies Laboratory , University of Chlef (Algeria)	The Euro-Mediterranean Research and Studies Laboratory , University of Chlef (Algeria)

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Abstract:

This study aims to examine the type and degree of competition between OPEC and non-OPEC countries based on production volumes during the period from 1965 to 2023, using important quantitative tools. The study reached the following conclusions :The market share of non-OPEC countries is 1.5 times larger than that of OPEC countries on average .The volatility of OPEC countries' elasticity is greater than the volatility of non-OPEC countries' elasticity .The results of the VAR model showed a negative (positive) relationship between the production quantity of OPEC and non-OPEC countries, with an impact size of -0.32 (0.35). However, the production of non-OPEC countries does not significantly affect the production of OPEC countries .The Granger and Toda-Yamamoto tests proved the existence of a unidirectional causal relationship, specifically from OPEC countries' production to non-OPEC countries' production.

Key words: competition by quantities, Hirschman-Hervandahl index, cross elasticity, VAR models, Granger test, Toda-Yamamoto test.

JEL Classification Codes: D43,L11,C32

* Corresponding author

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I. Introduction:

Today, the global oil market is characterized by fierce competition between two major groups: the (OPEC) and non-OPEC oil-producing nations. Together, these two groups dominate almost 80% of the global oil market, characterized by its complexity and wide-ranging impact on various economic sectors. At the heart of this market, we find important factors that are crucial for analyzing the competition between these two parties, most notably the volume of production or quantities produced, as a vital means of understanding oil market balances and supply and demand dynamics. This complex dynamic requires advanced analytical tools to understand and predict market changes, and here comes the role of quantitative methods as an effective tool in analyzing this competition, which is also considered one of the basic methods relied upon by researchers and economic analysts in studying the oil market. These methods provide a systematic framework for data analysis, modeling the strategic behavior of producers, and estimating the impact of production decisions on global prices. In this context, our main problematic is as follows :

I.1. Problematic : How can analysis competition between OPEC and non-OPEC countries using quantitative tools?

I.2. Hypotheses : The purpose of this study is to validate the hypotheses that follow:

- Due to the growing number of OPEC members, both the volume of production and the percentage of OPEC nations' contribution to the world's oil production exceed those of non-OPEC states.

- The production of non-OPEC countries is more sensitive to changes in the production of OPEC countries, due to their capabilities in determining the price.

--OPEC & non-OPEC production have a substantial reciprocal relationship because there are only two poles that contribute to global oil output.

I.3. Some empirical studies:

- A study (Luis, Gil-Alana, Dadgar, & Nazari, 2020, pp. 1-22), This study, titled "An Analysis of OPEC and Non-OPEC Positions in the World Oil Market: A Fractionally Integrated Approach," uses fractional integration to analyze the persistence of the time series in order to investigate world oil production as well as output by OPEC and non-OPEC nations. The results point to mean reversion in all three series, particularly in the case of OPEC and global production. Several structural fractures are also evident,

however the degree of persistence is comparatively consistent between the various sub-samples.

- A study (Funakoshi, 2009, pp. 27-47), titled: Analysis of market competitiveness based on produce amounts, This study uses the System Generalized Method of Moments to investigate how competition affects the rise of Total Factor Productivity (TFP). This study adopts a different methodology from conventional industrial organization studies, which use profit rates as performance measures and the Structure-Conduct-Performance framework. To provide a more thorough examination of how rivalry impacts TFP growth, it estimates Cobb-Douglas production functions for companies instead of utilizing concentration ratios and the Herfindahl-Hirschman

-A study (Ramcharran, 2002, pp. 79-106), entitled: Oil production reactions of OPEC and non-OPEC nations to price fluctuations: an empirical application of the competitive model ,This research uses the competitive model as an analytical framework to examine output patterns in most OPEC member and non-member nations. One noteworthy finding from the data is that none of the members' supply elasticity showed statistically significant increases .Additionally, supply elasticity was significantly negative for seven out of eleven members: Venezuela, Iran, Kuwait, Libya, Nigeria, Qatar, and the U E A considerable negative elasticity coefficient was seen when the entire image was examined, supporting the accuracy of estimations derived from the competitive model .Considering these results, It is possible to see the drop in OPEC's market share and the lower reliance on energy derived from oil as signs of changes in both prices and supply. These alterations imply that a more competitive model is being adopted by the world's crude oil market.

I.4. Research Structure :

In order to answer this problematic, the following points were addressed: First, the most important economic literature on competition and how to measure it in the market was presented. Then, general concepts about OPEC and non-OPEC countries were presented. After that, Using production quantities, the rivalry among OPEC and non-OPEC nations was examined, relying on the most important quantitative techniques: economic and statistical, in order to discover the size and nature of the competitive relationship between the two parties, Finally, we present the most important results and some advice.

II. Theoretical foundation of the research:

II.1. Basic general concepts about competitive strategy:

The concept of competitive strategy is linked to the general definition of strategy as a system of ideas about the desired future of the host entity's life, its priorities, and the directions of its activities to achieve this future, along with its tools and mechanisms.

Long-term offensive or defensive operations intended to improve market position while accounting for the level of competition are referred to as competitive strategy. This enables the organization to know these general strategies to transition into a survival plan in the market (Kostyaev & Ronzhin, 2023, p. 64) In the current competitive market, effective production management is a crucial factor in achieving success for organizations. One of the key strategies adopted by these organizations to compete is controlling the production volume, known as quantity-based competition strategies. In this context, we will discuss the study of oil markets, concentrating on both OPEC members and non-member nations. This competition in the markets is referred to as homogeneous goods competition, where there are few competitors on the supply side and many customers on the demand side, characterized by strategic interaction among the suppliers (BENMERIEM, 2017, p. 128) . These strategies are divided into two main types based on the time frame used, namely short-term strategies and long-term strategies, as shown in the following table

Table N°01: Homogeneous competition by quantities in the short and long term difference

	Short term	Long term
Dependency method	Depends on adjusting production quantities only	Depends on production capacities
Market structure	Fixed	Institutions can enter and exit the market
Costs	Fixed, unchangeable	Variable
Quantity produced	Relatively less	Relatively more
institution's The strategy	Maximizing profits or minimizing losses based on variable and current costs	The institution can adjust all its aspects, including factory size and the technology used.

Source : Mohammed Benmeriem, 2017, p132,p134.

II.2. Homogeneous competition by quantities in an oligopoly :

In markets dominated by a small number of firms, known as oligopolies, competition frequently takes place through quantity adjustments rather than product differentiation. This form of competition, where firms strategically decide on their production levels, is crucial for comprehending the dynamics and outcomes in oligopolistic market structures. The focus on quantity-based competition among firms offering similar products provides key insights into how these businesses interact and influence market conditions or identical in nature (pindyck & Rubinfeld, 2023, pp. 412-415)

II.3. Market competition measurement indicators:

Organizations rely on various indicators to assess their competitive position, considering them as important tools through which they seek to understand and improve their competitive standing in the contemporary business environment. These indicators, especially economic and statistical ones, deliver valuable insights into market dynamics, competitor performance, and potential growth opportunities. The most prominent indicators include the following :

II.3.1. Economic indicators :

Economic indicators for measuring competition include a diverse set of tools and criteria that help evaluate the degree of competitiveness in the market, These indicators include (Christoph & Dominik, 2022, p. 294)

a- Market share concentration index:

Market concentration means the extent to which production in a given market is concentrated in the hands of a limited number of producers. Therefore, in measuring industrial concentration, our interest focuses on the number and relative size of producers in each industry. In general, we say that an industry is more concentrated if the number of producing establishments decreases or the discrepancy between their shares in the industry increases (Arkabi & Bouchoucha, 2003-2015, p. 161). There are many indexes to measure the degree of market concentration, the most important of which are:

b-Concentration Ratio:

CR: displays the overall market shares of the companies operating in the industry. increased values of CR indicate increased market concentration. The value of CR ranges from 10 to 1. The following is the calculating formula:

$$Cr_n = \sum_{i=1}^r S_i \cdot 100, \quad S_i = \frac{q_i}{Q} \quad / \quad S_i \in [0,1]; i = 1, \dots, n_i$$

When, q_i : symbolizes the company's output i ; Q : overall industrial production

c- Herfindahl-Hirschman Index : It is a widely used measure to evaluate market competitiveness and concentration (investopedia). It is achieved by summing the squares of market shares for each company in the same industry, and it is calculated using the following relationship: (Geoffrey, 2024, p. 761) : $HHI = \sum_{i=1}^n (q_i / Q)^2 = \sum_{i=1}^n S_i^2$

II.3.2. Statistical indicators :

a- Correlation Coefficient : The simple correlation coefficient is considered one of the mathematical tools used in the field of statistics and is used to measure the degree of correlation between a pair of quantitative variables. Where, when the value of the simple correlation coefficient is close to 1, it indicates a strong correlation between the two variables under study, and vice versa. The closer the value is to zero, 0, the more it indicates no correlation between them (Michael, Alonso, & Olivia, 2023, p. 71)

b- Causation analysis: Causality explains the magnitude, nature, and direction of the relationship between two or more variables. Among the most important models that analyze causal relationships are : (Peixeiro, 2022, pp. 199-201)

- **The VAR model** : As seen by the following equation, the vector autoregressive model (VAR), a generalization of the model AR(p), which depicts the impact of prior values on the current value, depicts how different series interact with one another as they evolve throughout time.: $y_t = c + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \dots + \phi_p y_{t-p} + \xi_t$

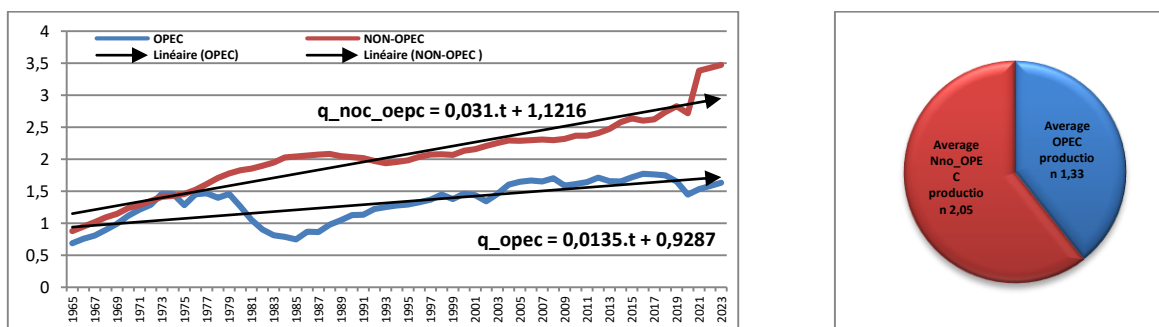
- **The Granger causality test** : A Granger-causality test can be used to investigate the causal links between time series variables (GCT) (DUVARCI & Hasan Engin , 2022) values $y_{2,t}$ can help predict time series $y_{1,t}$. If this is the case, then we say that $y_{2,t}$ Granger causality $y_{1,t}$.

III. Economic evaluation of the actual rivalry among non-OPEC and OPEC nations: In this element, we will analyze the reality of actual competition utilizing the most significant economic techniques, among OPEC and non-OPEC nations, in addition to discovering the extent of the relationship that exists between the two parties in the market.

III.1. The actual quantity-based competition among OPEC and non-OPEC nations:

Today, both inside and outside of the OPEC organization, oil-producing nations compete fiercely on the international market for oil. One of the primary issues of dispute in this battle is the volume of crude oil produced from OPEC and non-OPEC economies. In order to preserve price stability and a balance between supply and demand, each group aims to retain its market share and influence on worldwide prices. The OPEC countries modify production accordingly. In the meantime, non-OPEC nations, particularly the US and Russia, want to boost output in order to gain a larger portion of the market. This has caused the parties to engage in a sort of strategic exchange, but occasionally competition increases the supply of oil, which drives down prices. Alternatively, the parties could decide to lower production in order to support ,The parties might decide to cut output in order to keep prices stable, but competition is still a major influence on how the world oil market operates, The following figure shows the evolution of the production of oil quantities in OPEC and non-OPEC states during 1965 and 2023:

Figure N°01 Changes in the amount of Both OPEC while non-OPEC output over the course of the investigation (million tons per day)



Source: Prepared by researchers based on data from OPEC publications.

The figure shows that both series are continuously rising, with the exception of the OPEC countries' output series, which saw a sharp decrease in 1986 due to the oil crisis of that era. Conversely, we observe that, with the exception of the 1973–1974 period, non-OPEC nations have increased their production output relative to OPEC countries over the course of the study. Additionally, the general trend equation shows that the growth rate of production in non-OPEC nations reached an average value of 3% yearly, which is greater than the growth rate of production in OPEC countries, which reached 1% (see the general trend equation that appears in the figure).

.III.2. Analysis of the proportions of OPEC / non-OPEC markets:

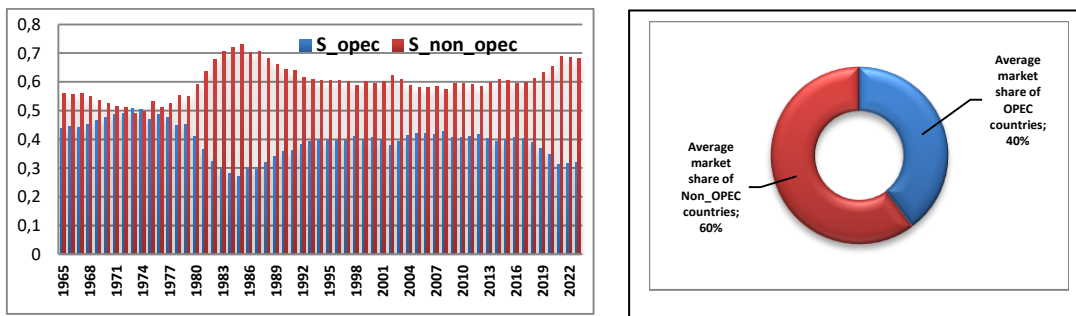
Market share is the percentage of a specific unit's production that is supplied to the market as a whole, That is: $S_i = \frac{q_i}{\sum q_i} = \frac{q_i}{Q}$.

S_i : represents the market share of the product, q_i : represents the production volume of product i , Q : It represents the total market production, which is the sum of the production of producers active in the market. And from it, then:

- OPEC/ Non OPEC countries: $s_{opec} = \frac{q_{opec}}{\sum q_i} = \frac{q_{opec}}{q_{opec} + q_{non_opec}}$, $s_{non_opec} = \frac{q_{non_opec}}{\sum q_i} = \frac{q_{non_opec}}{q_{opec} + q_{non_opec}}$

The evolution of OPEC and non-OPEC market shares from 1965 to 2023 is depicted in the following figure:

Figure N°02: Evolution of market shares of OPEC and non-OPEC countries:



Source: Prepared by researchers based on data from OPEC publications.

As the average percentage contribution of OPEC / non-OPEC nations to world production is assessed to be 40 and 60%, respectively, the data shows that, for the majority of the research years, non-OPEC nations' market shares increased in comparison to those of OPEC countries. Additionally, the share of non-OPEC nations is, on average, $0.6/0.4 = 1.5$ times that of OPEC nations. This shows how much non-OPEC countries dominate the market in comparison to OPEC nations.

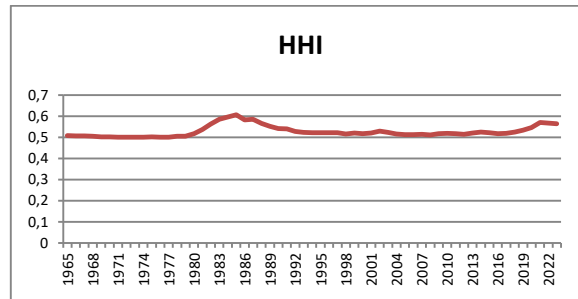
III.3. Measure the degree of market concentration: Hershman and Herfindahl index:

The total squared market shares of the producers are represented by this metric.(number n) that are associated with a certain industry. The closer its value is to 1, the more This suggests that industrial concentration is occurring at a rapid pace. The format of this index is as follows: (bouafia & argabia, 2022, pp. 119-134):

$$H = \sum_{i=1}^n \left(\frac{q_i}{Q} \right)^2 = \sum_{i=1}^n S_i^2 = S_{opec}^2 + S_{non_opec}^2$$

The value of this indicator during the period 1965-2023 can be represented in the following figure:

Figure N°03 Evolution of the Hirschman-Herfindahl index during the period 1965-2023



Source: Prepared by researchers based on data from OPEC publications.

As we can see from the above chart, the Hirschman index values vary between 0.6, which was recorded in 1985, and 0.5, which was recorded in 1974. This indicates that there are no notable swings in the index values. It centers around an average of 0.52, suggesting that the market's structure becomes close to being a duopoly market, which leads to significant strategic interactions between the two parties' actions.

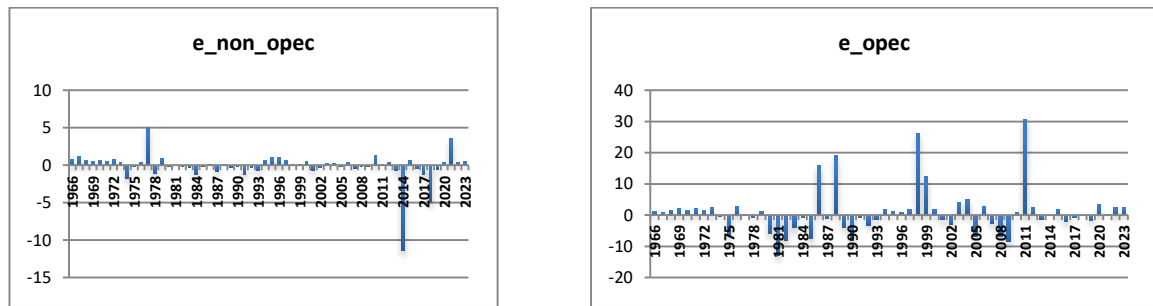
III.4. elasticity of intersection within OPEC and non-OPEC nations:

The elasticity of the intercept is defined as representing the percentage of change in one of the variables as a result of changing the other variable by 1%, where the elasticity of the intersection of OPEC represents the percentage of change in the volume of OPEC production as a result of changing the volume of production of countries Non-OPEC by 1%, i.e.:

, vice versa. Where: Δq_{opec} : represents the difference in OPEC production, Δq_{non_opec} : the difference in production of countries Non-OPEC.

The following chart illustrates the cross-elasticity evolution across the study period for OPEC & non-OPEC nations:

Figure N°04: Evolution of cross-flexibility of OPEC and non-OPEC countries



Source: Prepared by researchers based on data from OPEC publications.

We notice from the figure that the values of the elasticity of OPEC production in relation to the volume of production of non-OPEC countries generally carry significant fluctuations, showing the extreme sensitivity of OPEC production in relation to the volume of production of non-OPEC countries. Its largest value reached 30.49% in 2011. The lowest value recorded in 2018 was -0.2%, and in general the elasticity values revolve around an average of 0.89%. As for the elasticity of production of countries Non-OPEC, it ranges between the largest value of -11.39% in 2014 and 0.03% in 2011, and in general it fluctuates around an average of -0.1%. What can be concluded from the two figures is that the OPEC elasticities series is more fluctuating than the non-OPEC elasticity. This shows the high sensitivity of OPEC production in order to produce non-OPEC countries. We also find that the elasticities of OPEC countries are generally positive, which indicates that OPEC countries raise their production whenever the volume of production of non-OPEC countries increases. (Complementary competitive strategy) The opposite of the elasticity of non-OPEC countries, which is predominantly negative, which indicates that non-OPEC countries reduce their production whenever OPEC countries raise their production (Substitution competitive strategy).

III.5. Oil reserve evolution in OPEC & non-OPEC economies:

The quantity of oil reserves is seen as a basic element in competition because reserve ratios limit oil output, and increasing the size of oil reserves invariably increases market power. The evolution of oil reserves (measured in billion barrels) for both OPEC & non-OPEC nations is displayed in the following table:

Table N°02: Oil reserve volume evolution in OPEC & non-OPEC nations

	End of 2000	End of 2010	%	End of 2020	%
OPEC Countries reserves	833,06	1137,7	36,56 %	1214,7	6,7 %
Non-OPEC countries reserves	468,2	499,1	6,6 %	517,7	3,7 %
Total World	1300,9	1636,9	25,82 %	1732,4	5,8 %
OPEC's percentage of global reserves	64,04%	69,5%	-	70,11 %	-
Non-OPEC's percentage of global	35,06%	30,5%	-	29,89 %	-
The ratio of OPEC countries reserves to non-OPEC countries	1,78 %	2,28%	-	2,35 %	-

Source: Prepared by researchers based on data from the OPEC website

The table shows that, in comparison to non-OPEC nations, the volume of oil reserves in OPEC countries has significantly increased and has nearly doubled throughout the course of the study., as we find that the percentage of reserves of OPEC & non-OPEC nations Of the global reserve is estimated in average by 70 and 30% , respectively. We also note that the reserve growth rate in OPEC nations is greater than in non-OPEC countries during the entire study period, as it reached 36,56 % and 6,6 % for OPEC and non-OPEC countries between the years 2000 and 2010, respectively, and 6,7 % and 3,7 % between the years 2010 and 2020, respectively. This is due to the increase in exploration and drilling of oil wells in OPEC countries. And the number of countries joining OPEC has increased over the past years.

VI. A statistical examination of the true competitive environment existing between OPEC and non-OPEC nations:

In this element, the most important statistical techniques will be used to analyze the intensity and nature of competition by quantities produced between OPEC and non-OPEC countries, through estimating simple and cross correlation coefficients, in addition to causality tests in the short and long terms: the Granger and Toda-Yamamoto test, to clarify the direction of the relationship between the quantities produced by both OPEC and non-OPEC. Our applied study relies in its data on statistics published by OPEC, The analysis is based on annual data series during the period (1965-2023) for the following variables: The volume of OPEC countries' production of crude oil (in million

tons), which we symbolize as $Q_{_opec_t}$, The volume of crude oil production of countries non-OPEC $Q_{_non_opec_t}$.

VI.1. Simple and cross correlation coefficients between OPEC and non-OPEC production quantities:

VI.1.1. Simple correlation coefficients: Based on the outputs of the EViews 12 program, we obtained the following results :

Figure N°05: Results of testing simple correlation coefficients between quantities

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Covariance Analysis: Ordinary
Date: 06/25/24 Time: 22:04
Sample: 1965 2023
Included observations: 59
  
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	Q_NON_OP...	Q_OPEC
Q_NON_OPEC	0.313625 1.000000 ----	
Q_OPEC	0.107944 0.626842 6.074027 0.0000	0.094551 1.000000 ----

Source: Prepared by researchers based on Eviews 12.0 program

Through the results of the simple correlation coefficient test between the production quantities of the two parties, it becomes clear that the correlation is strong, reaching 0.62, which is significant (prob = 0,00 < 0,05), and this indicates the existence of a strong relationship between them.

VI.1.2. coefficients of cross-correlation between production quantities within and outside of OPEC:

The following table displays the results of a cross-correlation test that was performed between these variables using lag periods and leading (future) periods up to 3 years in order to further demonstrate the strength and significance of the correlation between the amount of OPEC & non-OPEC industrial production.

Table N°03: Cross correlation coefficients between OPEC & non-OPEC industrial production quantities:

Number of time periods (p)	Cross correlation coefficients	
	$cross(Q_{opec_t}, Q_{non_opec_{t-i}})$	$cross(Q_{opec_t}, Q_{non_opec_{t+i}})$
0	0.62*	0.62*
1	0.58*	0.53*
2	0.57*	0.45*
3	0.57*	0.37*

Source: Prepared by researchers based on Eviews 12 program

Note: (*) means significant at 5%.

It is clear from this table that there is a strong and positive correlation at all lagging and leading periods. Also, all of these cross-correlation coefficients were significant at the 5% significance level, as shown in Appendix No. (01) that all statistics of the values of the correlation coefficients fall outside of the interval of confidence. On the other hand, it is noted that the size of the lagging correlation coefficients is larger compared to the future correlation coefficients, but in general all the values of these coefficients were greater than 0.5, which indicates the strength and significance of the relationship between the volume of OPEC & non-OPEC industrial production during the study duration. In general, the estimated sign of the cross-correlation coefficients can be considered consistent with what is expected theoretically.

VI.2. Testing causality using the Granger test (short-run causality):

When dealing with time series data in the near term, the Granger test is used to confirm the degree of a reciprocal link between two or more variables. Generally speaking, the following fundamental procedures are used to apply the Granger test:

- Studying the stationary of time series:

The stationarity of the study variables is evaluated by means of the Augmented Dickey-Fuller (ADF) along with Phillips-Perron (PP) tests. Using specifically created software in EViews 12, it is possible to acquire the results for all variables at the same time (Results in Appendix No. 02). The following table provides a summary of these findings:

Table N° (04): Degrees stationary of the study variables.

Type I(1)
Q_non_opec ,Q_opec

Source: Prepared by researchers based on Eviews 12 program

The table in Appendix No. 2 shows that the estimated statistics values for the ADF & PP test statistics are smaller (in absolute value) than the tabular statistics in all three models at the 5% significant level for all variables., We therefore agree with the null hypothesis. Furthermore, not all series show a significant trend in the third model, suggesting that some series are DS type non-stationary. All three models' computed test statistics surpass the tabular ones at the 5% significance level when the series are differenced to the first order, showing that the models are first-order stationary. I (1).

- Determining the optimal lag period: The Granger test requires the introduction of time-delayed variables, the optimal number of which must be determined through statistical criteria: AIC, SC, HQ for the var(p) model, where the lowest value corresponding to the optimal lag is chosen, and the following table shows this:

Table N° (05): Values of statistical criteria at lag periods

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-39.34671	NA	0.015418	1.503517	1.576511	1.531744
1	107.8412	278.3189	7.41e-05*	-3.840083*	-3.484333*	-3.618633
2	115.2215	13.41878	8.45e-05	-3.703315	-3.461266	-3.685099*
3	117.3027	3.632624	8.03e-05	-3.756461	-3.245503	-3.558869
4	123.6023	10.53752*	7.48e-05	-3.826236	-3.183137	-3.586037

Source: Prepared by researchers based on Eviews 12 program

The table indicates that the majority of criteria selected an ideal lag period of one. Ultimately, we were able to collect the Granger test findings by using the Eviews 12.0 application, which are presented in the table below. (Results of Appendix No. 03):

Figure N°06: Granger test results

Null hypothesis H_0	F_{stat}	$prob(F_{stat})$	decision
Non-OPEC production does not cause OPEC production	0,1	0,74	Accept H_0
OPEC production does not cause non-OPEC production	6.54	0,01	Reject H'_0

Source: Prepared by researchers based on Eviews 12 program

From the results of the table above, it is clear to us that $F_{stat} = 0.1$ is less than the tabulation value at 5% level of significance, as well as ($prob:0.74 > 0.05$), and this means that H_0 is not rejected, On the other hand, in the second equation, we found that $F_{stat} = 6.54$ which, at the 5% significance level, exceeds the tabulated value, as well as ($prob:0.01 < 0.05$), i.e. rejection of H'_0 , and from it: the variable DQ_opec_t causes the variable $DQ_non_opec_t$ and the variable $DQ_non_opec_t$ does not cause the variable DQ_opec_t in the short term.

VI.3. Testing causality using Toda - Yamamoto test (1995) (long-run causality):

This test came to cover the Defects found in the Granger causality test, which assumes stationary series. It is also a test that suffers from the problem of bias and is related to the presence of cointegration according to Granger's representation formula. However, the Toda- Yamamoto test does not care about the degree of integration of the variables, and it is a test of long-term causality. In general, to do this test, the following steps must be taken: Study the stationary of variables to determine their degree of integration. We then determine the optimal lag for the VAR model, and then add to all variables a lag of $(k+dmax)$, where k represents the number of VAR lags entered and $dmax$ is the highest degree of stationary of the time series used in the model .

VI.3.1. Estimating the VAR model: We determine that $dmax = 1$ is the maximum degree of variable integration that is feasible based on the preceding procedures. Additionally, the VAR model's ideal degree of lag, as determined by statistical criteria, is $k = 1$, from which the VAR (2) model will be derived. based on the var(2) model's findings, which are displayed in Appendix 04.The following mathematical formulas provide the role of OPEC & Non-OPEC States:

Results of estimating the OPEC countries' model

$$Q_opec_t = 0,1 + 1,18 \cdot Q_opec_{t-1} - 0,27 \cdot Q_opec_{t-2} - 0,03 \cdot Q_non_opec_{t-1} + 0,04 \cdot Q_non_opec_{t-2}$$

(1,78)** (8,72)*** (2,01)** (-0,2) (0,3)

$R^2 = 0,91$ $F_{stat} = 141,006$ $Log\ likelihood = 60,06$ $n = 57$

Results of estimating the Non-OPEC countries' model

$$Q_non_opec_t = 0,03 - 0,32 \cdot Q_opec_{t-1} + 0,35 \cdot Q_opec_{t-2} + 0,92 \cdot Q_non_opec_{t-1} + 0,06 \cdot Q_non_opec_{t-2}$$

(0,61) (-2,32)** (2,52)** (7,05)*** (0,46)

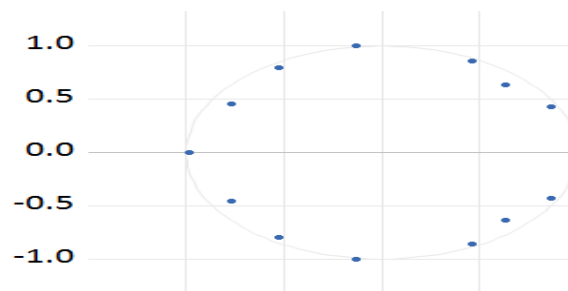
$R^2 = 0,97$ $F_{stat} = 469,32$ $Log\ likelihood = 58,64$ $n = 57$

Note:- * Significant at 10%, ** Significant at 5%, *** Significant at 1%

VI.3.2. Diagnosing the VAR(2) model: Also, before applying causality, we must first ensure that the VAR(2) model is valid by verifying the following most important diagnostic tests:

- **Examination of the VAR(2) model's stability :** Several tests of unit roots are employed to confirm the stability of the VAR(2) model. The results of this test are displayed in the figure below. The autoregressive vector results are deemed stable if the inverse of the polynomial's unit roots is inside the circle:

Figure N°08: The unitary circle



Source: Prepared by researchers based on Eviews 12 program

The stability of the VAR(2) model is demonstrated by the fact that the inverse unit roots of the polynomial are clearly inside the unit circle in the previous picture. However, we also mention the outcomes of the other crucial diagnostic tests in the table that follows:

Diagnostic tests	JB	LM	WITE
<i>statistic</i>	$\chi^2_{stat}(4) = 3.61$	$Rao\ F_{stat}(4,56.0) = 1.79$	$\chi^2_{stat}(120) = 131.99$
<i>probability</i>	0.16	0.14	0.21

- The Jarque-Berra test statistic to detect the normality of the distribution of the model's residuals indicates that the probability values for all tests are greater than 5%, meaning accepting the null hypothesis which indicates that the model's residuals follow a normal distribution.

- The LM statistic for testing the autocorrelation of the model's residuals indicates acceptance of the null hypothesis, indicating that since the probability value is higher than 5%, there is no autocorrelation between the residuals of the model.

- The WITE statistic for testing the homogeneity of the variance of the model residuals indicates that the probability values corresponding to the WITE statistic are greater than 5%, and therefore the null hypothesis of homogeneity of the residual variance is accepted.

VI.3.3. Toda-yamamoto causality test:

Relying on the M-WALD test based on the results of estimating the previous VAR(2) model where $k=1$ and $d_{max}=1$, the results of Toda Yamamoto's long-term causality test can be summarized in the following table (Results of Appendix No. 05)

Table No. (6): Toda yamamoto's long-run causality test results

Dependent variable	Exogenous variables	df	χ^2_{stat}	$prob(\chi^2_{stat})$	Decision
Q_OPEC	Q_Non_OPEC	2	0.26	0.87	Q_Non_OPEC does not cause Q_OPEC
	ALL	2	0.26	0.87	
Q_Non_OPEC	Q_OPEC	2	6.37	0.04	Q_OPEC causes Q_Non_OPEC
	ALL	2	6.37	0.04	Q_Non_OPEC

Source: Prepared by researchers based on Eviews 12 program

We draw the following conclusions based on the causality test results displayed in the above table:

- The causality relationship between the amount of OPEC and non-OPEC production:

We have $prob(\chi^2_{stat})=0.87 > 0.05$ and this means accepting the hypothesis H_0 and this means that the variable Q_Non_OPEC does not cause the variable Q_OPEC in the long run at a 5% significance level, On the other hand, we find that in the second equation $prob(\chi^2_{stat})=0.04 < 0.05$ and from it we reject the hypothesis H_0' that is, the variable

Q_OPEC causes the variable Q_Non_OPEC, in the long run at 5% Significant level .

V. Analysis and discussion of results :

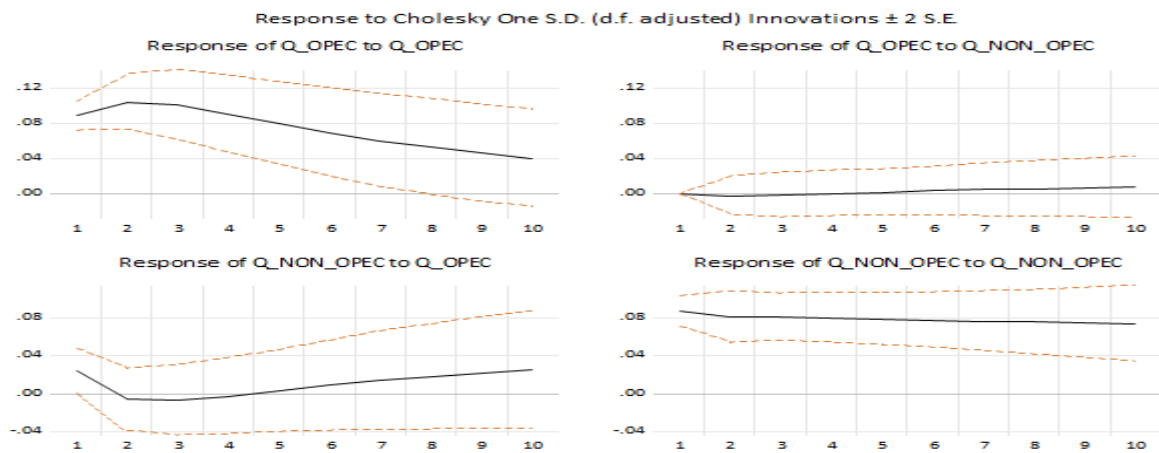
- With the effect size reaching 1.18 (-0.27), we can see from the OPEC nations' equation that the volume of output lagged by one year (or two years) has a positive (inverse) and significant effect on the volume of current production. This indicates that the volume of

current production will grow (drop) by 1.18 (0.27) million tons, respectively, if the volume of OPEC production in the last year (two years) increases by 1 million tons. However, the amount of production in non-OPEC nations has little bearing on the amount of production in OPEC nations.

- Through the equation for non-OPEC countries, We also note that the current level the production of non-OPEC nations is significantly impacted, either positively or negatively, by the production volume of OPEC nations a year (or two) later; the effect magnitude reached -0.32 (0.35). This implies that non-OPEC nations' current production level will decrease (increase) by 0.32 (0.35) million tons., respectively, if the level of OPEC production from the previous year (or two years) increases by 1 million tons. Conversely, the effect size was 0.92, indicating a substantial and positive link between the present production output of non-OPEC countries and those that are one year behind schedule. This indicates that a one million ton rise in non-OPEC nations' production volume last year would result in a 0.92 million ton increase in those countries' current production level.

- There is a significant correlation within the production levels of OPEC and non-OPEC nations, but only in one direction: in the short and long terms, from OPEC countries' production towards non-OPEC countries; in other words, non-OPEC countries' production is influenced by rival OPEC countries' production: This outcome is regarded as economically reasonable since it can be explained by the fact that, because of its size, OPEC's production changes have an impact on worldwide supply and demand, which in turn affects oil prices globally. As a result, non-OPEC countries' output will unavoidably alter., It had no lasting or short-term significance. This conclusion can also be justified economically since it shows that the output of the OPEC member nations, which is organized as an explicit cartel and determined in advance by OPEC decisions, is produced. Thus, exogenous variables—such as the production of rival nations—generally have little direct impact on the output of OPEC members. This is where we discover that OPEC member nations produce in accordance with OPEC decisions rather than on their own.

V.1. Shock analysis (response functions): Analyzing random shocks to the variables based on the outcomes of the preceding VAR(2) model outputs can further confirm the previous Toda-Yamamoto test results. The process involves calculating the impact of an abrupt alteration in one variable on the other variables. Based on estimations of reaction functions spanning ten years, we applied a shock of one standard deviation, estimated at 0.08, in the first period on the volume of OPEC output.



Source: Prepared by researchers based on Eviews 12 program

we notice that the volume of non-OPEC production remained the same during the same period. But there is a change in the following periods that reached 0.007 during the last period, and this means that any change that occurs in the volume of OPEC countries production will inevitably affect the volume of Non OPEC production and in the same direction in general (except for the second and third periods, which indicates the inverse relationship in the short term). However, the size of the effect was generally weak.

- However, the volume of production in OPEC countries changes by 0.02 during the same period and stays relatively constant in all subsequent periods when we apply a shock, estimated at 0.08 in the first period, to the volume of production in non-OPEC countries. The value of the coefficients in the second, third, and fourth periods was negative, indicating an inverse relationship between the volume of production in OPEC and non-OPEC nations in the short run, while the remaining coefficients were positive, indicating a positive relationship among the two variables in the long run.

IV. Conclusion :

In this research paper, many quantitative methods and techniques were used, including economic and statistical methods. The most important of them is the causality test according to Granger in the short term, as well as the causality test according to the Toda Yamamoto method to test causality in the long term, to examine the type and degree of oil production competition between OPEC and non-OPEC nations between (1965 -2023), and in general the study reached the following results:

- By examining the growth of both OPEC / non-OPEC production, we discovered that while both parties' volumes of production are continuously rising, non-OPEC countries'

production has consistently outpaced OPEC countries' production for the duration of the study, with the exception of the years 1973–1974.

- Additionally, we discovered that, for the majority of the studied periods, non-OPEC nations' market shares increased relative to those of OPEC countries. On average, this difference in share is bigger by 1.5, indicating that non-OPEC countries dominate the market more than OPEC.

- Additionally, we discovered that the Hirschman index varies around an average of 0.52 and does not exhibit any notable changes in its values. This implies that there are very few structural differences between the oil market and a duopoly.

- We discovered that OPEC elasticity is more volatile than non-OPEC elasticity by using the cross-elasticity study. This demonstrates how highly sensitive OPEC production is to non-OPEC countries' production. Additionally, we discover that the elasticity of OPEC nations is often positive, meaning that when the volume of production of non-OPEC nations rises, OPEC nations increase their output (complementary techniques). Nonetheless, non-OPEC nations' elasticity is primarily negative, meaning that if OPEC nations raise their output, non-OPEC nations decrease it (substitution tactics).

- The volume of OPEC and non-OPEC output has a considerable and positive association, according to the results of the simple and cross-correlation coefficients. These correlations are high, with the majority of them above the value of 0.5.

- The volume of production of OPEC countries during the past two years and the volume of production of non-OPEC countries have a positive relationship, with an effect size of 0.35 and -0.32, respectively, according to the VAR model results. The volume of production of OPEC countries during the past two years and the volume of production of non-OPEC countries have an inverse relationship. However, there is no discernible difference between the production of OPEC / non-OPEC nations.

- There is agreement between Granger and Toda-Yamamoto test in the results of the causality study: the two tests proved the existence of a causal relationship in only one direction, which is from the production of OPEC countries to Non-OPEC production , this shows the rigid of OPEC countries' production due to the presence of the cartel

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Annexes:

Appendix No. 02: Results of stationary tests

A1Level		UNIT ROOT TEST TABLE (PP)	
	Q_OPEC	Q_NON_OPEC	
With Cons...	t-Statistic -2.0592 Prob. 0.2616 no	t-Statistic -1.2497 Prob. 0.9735 no	
With Cons...	t-Statistic -2.3349 Prob. 0.4099 no	t-Statistic -1.2357 Prob. 0.8933 no	
Without C...	t-Statistic 0.5478 Prob. 0.8316 no	t-Statistic 3.7346 Prob. 0.9999 no	
At First Difference		d(Q_OPEC) d(Q_NON_OPEC)	
With Cons...	t-Statistic -5.8981 Prob. 0.0000 ***	t-Statistic -8.3082 Prob. 0.0000 ***	
With Cons...	t-Statistic -5.8861 Prob. 0.0000 ***	t-Statistic -8.3090 Prob. 0.0000 ***	
Without C...	t-Statistic -5.8203 Prob. 0.0000 ***	t-Statistic -7.0635 Prob. 0.0000 ***	
A1Level		UNIT ROOT TEST TABLE (ADF)	
	Q_OPEC	Q_NON_OPEC	
With Cons...	t-Statistic -1.9234 Prob. no	t-Statistic 0.2125 Prob. no	
With Cons...	t-Statistic -1.9575 Prob. 0.6584 no	t-Statistic -1.1179 Prob. 0.9170 no	
Without C...	t-Statistic 0.9055 Prob. 0.9004 no	t-Statistic 3.5949 Prob. 0.9999 no	
At First Difference		d(Q_OPEC) d(Q_NON_OPEC)	
With Cons...	t-Statistic -5.7951 Prob. 0.0000 ***	t-Statistic -8.3492 Prob. 0.0000 ***	
With Cons...	t-Statistic -5.7177 Prob. 0.0001 ***	t-Statistic -8.3488 Prob. 0.0000 ***	
Without C...	t-Statistic -5.7172 Prob. 0.0000 ***	t-Statistic 0.1723 Prob. 0.7324 no	

Notes: (*)Significant at the 10%, (**)Significant at the 5%, (***) Significant at the 1%, and (no) Not Sig...
*Mackinnon (1996) one-sided p-values.

Appendix No. 04: Estimation results of Var (2) model

Vector Autoregression Estimates
Date: 07/10/24 Time: 02:11
Sample (adjusted): 1967_2023
Included observations: 57 after adjustments
Standard errors in () & t-statistics in []

	Q_OPEC	Q_NON_OPEC
Q_OPEC(-1)	1.184990 (0.13575) [8.72893]	-0.323894 (0.12917) [-2.32730]
Q_OPEC(-2)	-0.273448 (0.13577) [-2.01402]	0.351329 (0.13131) [2.52410]
Q_NON_OPEC(-1)	-0.026895 (0.12809) [-0.20997]	0.926798 (0.13131) [7.05802]
Q_NON_OPEC(-2)	0.040970 (0.13218) [0.30995]	0.063213 (0.13551) [0.46648]
C	0.102496 (0.05734) [1.78737]	0.036357 (0.05879) [0.61848]
R-squared	0.918685	0.973047
Adj. R-squared	0.909091	0.970974
Sum sq. resid	0.405524	0.426302
S.E. equation	0.053820	0.090543
F-statistic	141.0005	489.3247
Log likelihood	60.06382	58.64579
Akaike AIC	-1.932064	-1.982344
Schwarz SIC	-1.752849	-1.703129
Mean dependent	1.353721	2.091737
S.D. dependent	0.292926	0.531450
Determinant resid covariance (dof adj.)	5.93E-05	4.93E-05
Determinant resid covariance		120.8818
Log likelihood		-3.890591
Akaike information criterion		-3.532161
Schwarz criterion		10
Number of coefficients		

Appendix No. 01: Results of the cross-correlation coefficient

Date: 06/25/24 Time: 22:12
Sample: 1965 2023
Included observations: 59
Correlations are asymptotically consistent approximations

Q_NON_OPEC,Q_OPEC(-i)	Q_NON_OPEC,Q_OPEC...	i	lag	lead
		0	0.6268	0.6268
		1	0.5879	0.5385
		2	0.5722	0.4558
		3	0.5724	0.3772

Appendix No. 03: Granger test results

Pairwise Granger Causality Tests
Date: 07/10/24 Time: 02:08
Sample: 1965 2023
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
DQ_NON_OPEC does not Granger Cause DQ_OPEC	57	0.10398	0.7484
DQ_OPEC does not Granger Cause DQ_NON_OPEC		6.54409	0.0134

Appendix 05: Toda-Yamamoto test results

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 07/10/24 Time: 02:14
Sample: 1965 2023
Included observations: 57

Dependent variable: Q_OPEC	Excluded	Chi-sq	df	Prob.
	Q_NON_OPEC	0.261479	2	0.8774
	All	0.261479	2	0.8774
Dependent variable: Q_NON_OPEC	Excluded	Chi-sq	df	Prob.
	Q_OPEC	6.377192	2	0.0412
	All	6.377192	2	0.0412