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An Empirical Analysis of Supply and Demand Determinants of Global Oil Prices: The Role of OPEC

Srđan Stevandić[1]*

[1] Banka Poštanska štedionica AD Banja Luka, Banja Luka, Bosnia and Herzegovina

ABSTRACT

This paper examines the key determinants influencing global oil prices from both supply and demand perspectives, including structural and shock-related factors such as the COVID-19 pandemic. Particular emphasis is placed on the influence of OPEC production quotas, non-OPEC production volumes, trade openness, industrial production, and shock-related factors such as the pandemic and major geopolitical events. The analysis covers the period from 2000 to 2023 and applies multiple linear regression, including OLS, Newey-West, and Bootstrap techniques, to test three primary hypotheses concerning the relationship between oil prices and these explanatory variables. The results reveal that a one percent reduction in OPEC quotas leads to a 1.59 percent increase in global oil prices, confirming the organization's significant influence on the supply side. Additionally, the findings show that a one percent increase in global industrial production results in a 12.06 percent price increase, underscoring the strong link between economic activity and oil demand. Conversely, greater trade openness is associated with lower oil prices; specifically, a one percent increase in openness correlates with a 1.62 percent price decrease, likely due to enhanced competition and greater supply efficiency. The COVID-19 variable was also found to have a statistically significant and negative effect on oil prices during the crisis period. These relationships are statistically significant and robust across all model specifications. In contrast, the variable representing non-OPEC production volumes yields a statistically significant positive effect only in the OLS and Newey-West models, while turning statistically insignificant in both Bootstrap models, highlighting potential sensitivity to distributional assumptions and underlying structural heterogeneity. Additionally, the 2001 geopolitical shift, included as a structural dummy variable, did not show statistical significance, suggesting that global oil markets may have absorbed its impact without lasting price disruption.

Keywords: *OPEC quotas, global oil prices, trade openness, COVID-19 shock, oil market concentration, Herfindahl-Hirschman Index (HHI), oil supply and demand*

JEL Classification: Q41, Q43, Q48, F14

INTRODUCTION

Oil remains one of the most strategically important commodities in the modern global economy, with a historical legacy dating back to the second half of the 19th century. The first commercial oil drilling, conducted in 1859 in Titusville, Pennsylvania (USA), marked the beginning of the modern oil industry. By the turn of the 20th century, Standard Oil, founded by John D. Rockefeller, had established a near-monopoly over oil production, refining, and distribution in the United States, embedding oil deeply within the foundations of industrial and economic development. In the mid-

* E-mail: srdjanstevandic97@gmail.com

20th century, the discovery of vast oil reserves in the Middle East shifted the epicenter of global oil production. In 1960, five major oil-producing countries, Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela, established the Organization of the Petroleum Exporting Countries (OPEC). The aim of OPEC was to coordinate petroleum policies among its member states in order to stabilize markets and secure fair and stable revenues for producers. OPEC's influence became globally visible during the oil crises of the 1970s, when it used production limits as a strategic tool, leading to steep increases in oil prices. As noted by Yergin (1991), "the energy shocks of the 1970s were the first global reminder that the 20th-century economy was still powered by a 19th-century fuel." While the 1970s marked the emergence of oil as a geopolitical instrument, the early 21st century illustrated its deeper integration into global financial systems. During the mid-2000s super-cycle, oil exporters accumulated unprecedented surpluses. Balaban et al. (2013) note that these windfalls were "placed through investment funds," primarily sovereign-wealth vehicles investing in U.S. assets. Such petrodollar recycling amplified global leverage; consequently, when the 2008 financial crisis struck, the reversal in risk appetite collapsed oil demand and prices well ahead of OPEC's announced output curbs. The chain of events confirms that liquidity effects can reinforce, and sometimes outpace, supply-side interventions.

In the contemporary era, oil markets are shaped by the complex interplay of globalized consumption and production. Major consumers like the United States, China, India, and the European Union drive demand, while producers, both inside and outside OPEC, compete to maintain market share. At the same time, the world is increasingly focused on the challenges of climate change and energy transition, promoting the development of renewable energy sources and technologies aimed at reducing carbon emissions. Although oil remains central to the global economy, there is a growing emphasis on sustainability, efficiency, and diversification. Oil price volatility has been further complicated by technological advancements, geopolitical risks, and global economic shocks, most notably the COVID-19 pandemic. The global lockdowns in 2020 triggered an unprecedented collapse in industrial activity and oil demand, resulting in record-low and even negative oil prices. COVID-19 did not merely interrupt supply; it severely hit external demand and prices of export commodities (Bodroža & Lazić, 2021), including crude oil. For economies deeply embedded in global trade networks, the shock was immediate: "Economies with higher levels of trade integration are particularly exposed to reduced global demand and distortions in global supply chains" (Stanceva Gigov, 2020). This explains why the 2020 demand collapse magnified the price impact of OPEC's supply cuts, sending Brent and WTI to historic lows. In April 2020, WTI futures briefly traded below zero, illustrating the severe market imbalance. Amid these dynamics, OPEC and its expanded coalition OPEC+, which includes Russia and other non-member producers (since 2016), continue to play a decisive role in global supply coordination. Their joint production agreements have become crucial mechanisms for stabilizing prices and balancing global supply and demand. Studying OPEC's influence, alongside other economic and structural factors, is essential for policymakers, analysts, and scholars seeking to understand the price-setting mechanisms in global oil markets.

Existing research leaves several critical questions unanswered. Most empirical studies still treat OPEC as a single actor and exclude the post-2016 OPEC plus era, so it remains unclear whether formal quota decisions continue to dominate prices once large non-OPEC producers such as Russia participate in coordinated agreements. Global GDP is commonly used as a proxy for demand, although industrial production is the energy-intensive component most directly linked to oil use; very few papers include an explicit industrial-activity measure, and virtually none test its explanatory power during the shale revolution or the recent expansion of emerging-market consumption. Much of the literature ends in 2019, failing to capture the unprecedented supply-demand decoupling caused by COVID-19 or the episode of negative WTI prices in April 2020. In addition, recent work rarely measures how the competitive landscape among producers has changed; the Herfindahl–Hirschman Index, a standard in competition analysis, has seldom been applied to crude-oil supply in the last decade, leaving the link between shifting market concentration and price dynamics opaque.

This study addresses those gaps by disentangling the influence of formal OPEC quotas from the production behavior of non-OPEC suppliers, incorporating global industrial production, introducing a COVID-19 dummy to isolate the 2020 shock, and calculating the annual Herfindahl-Hirschman Index for crude-oil supply to document changes in market concentration. The HHI is analyzed descriptively rather than entered as a regressor. Together, these elements permit the first unified assessment of coordinated supply actions, competitive production, refined demand pressures, unprecedented shocks, and structural market power across the years 2000 to 2023, a period that captures the shale boom and the pandemic disruption. The main objective of the thesis is to identify and empirically quantify the key determinants of global oil prices over that period, with particular attention to OPEC production quotas, non-OPEC output, industrial activity, trade openness, and major global shocks, including the 2001 geopolitical shift and the COVID-19 pandemic. A multiple linear-regression framework is employed in which the dependent variable is the equally weighted average price of WTI, Brent, and Dubai crude. Explanatory variables comprise OPEC quotas, non-OPEC production, global industrial production (as a share of GDP), oil-trade openness, Global Shock 2001 and a COVID-19 dummy capturing short-term demand-side disruptions in 2001 and 2002. A synthetic variable for the 2008–2009 global financial crisis was deliberately excluded in order to isolate and better observe the statistical significance and magnitude of the COVID-19 shock, which constitutes the primary contemporary disruption under examination in this study. According to Tomić et al. (2021), the economic consequences of the COVID-19 pandemic triggered a global recession whose severity exceeded even that of the two World Wars and the Great Depression of the 20th century. For this reason, the model focuses exclusively on capturing the effects of the COVID-19 crisis through a dedicated dummy variable. Data are drawn from OPEC, the International Energy Agency (IEA), the U.S. Energy Information Administration (EIA), the World Bank, and the Federal Reserve Economic Data (FRED).

This study contributes to the existing literature by combining the effects of OPEC's cartel policies, macroeconomic demand factors, and global disruptions into a unified analytical framework. Additionally, the paper evaluates market concentration through the Herfindahl-Hirschman Index, offering insights into the evolution of competition among oil producers during the studied period.

LITERATURE REVIEW

The analysis of oil prices, as a key global energy resource, presents a complex research challenge due to the multitude of international and macroeconomic determinants influencing them. Previous empirical studies have employed various approaches and methodologies to understand the causes and consequences of oil price fluctuations. One major research direction focuses on the impact of global economic factors. For instance, Albaity and Mustafa (2018) investigated the effect of exchange rates, gold prices, and stock indices on oil prices in GCC countries using panel data methods. Similarly, Alredany (2018) and Chatziantoniou et al. (2021) explored the role of OPEC quotas and financial variables in determining global oil prices.

Production quotas are the primary lever through which the Organization of the Petroleum Exporting Countries shapes the global oil market. Their influence travels along two routes. First, by adjusting current supply, quotas affect the physical balance of the market. Second, they work indirectly through the macro-financial cycles of member states. Behnam (2011) provides evidence for this second channel in a panel study of 21 Middle-Eastern economies, noting that "oil extraction has a positive effect on foreign direct-investment attraction and economic growth." Larger inflows of foreign direct investment and faster GDP growth widen the fiscal space of oil-exporting governments, allowing them to finance the maintenance or expansion of upstream capacity. OPEC quotas, therefore, function not only as an immediate supply switch but also as a seedbed for future production. Because of that dual role, member states regularly revisit their quotas to preserve cartel discipline and stabilize prices (Baumeister and Peersman, 2012). Limiting output helps OPEC defend market share and protect revenue objectives (Mercure et al., 2021). At the same time, the formal quota system raises internal transaction costs, a problem observed since its introduction in 1982 (Smith, 2005). Verleger (1982) underlines the centrality of quotas, showing that spot-market prices serve as the benchmark for official OPEC postings, with quota allocations mediating the pass-through. Several empirical studies sharpen this picture. Alhajji and Huettner (2000), using a structural simultaneous-equations model for 1973–1994, find that OECD income and U.S. price controls push prices up, while higher non-OPEC costs and OPEC user costs pull them down. Bremond, Hache and Joëts (2012) employ cointegration and Granger causality tests covering 1973–2009 and show that OPEC's influence weakened after the counter-oil-shock years, shifting from dominant price setter to price taker. Smith (2005), combining standard and novel statistical tests, still detects cooperative behaviour but again highlights the quota-related transaction-cost burden. Verleger's analysis of 1975–1980 data indicates that Rotterdam spot prices drive official postings with a lag, whereas transport and refining costs have a negative effect. A broader literature supports and refines these findings. Guidi et al. (2006) link OPEC decisions to swings in both oil and equity prices. Bina and Vo (2007) trace the dynamic price response to OPEC policy between 1983 and 2005. Kisswani (2011) examines price formation through extraction volumes, Ibrahim and Omoteso (2022) analyze the effects of quota cheating on price stability, and Horan et al. (2004) investigate volatility transmission to futures markets. Across these studies, exchange rates, financial speculation and geopolitical shocks consistently appear as key price drivers alongside quotas and production costs. Together, the literature confirms that OPEC remains central to price formation, though its influence evolves over time and across economic contexts. Important research gaps persist, including the long-term impact of climate policy and the energy transition, the effect of technological change on demand elasticity and the role of governance in oil-rich states. Addressing these issues would deepen our understanding of how production control, market openness and exogenous shocks jointly shape oil prices in the years ahead.

Methodological approaches in the oil-price literature vary widely, from classical regression and principal-component analysis to more flexible frameworks such as time-varying parameter VAR and ARDL models. Albaity and Mustafa (2018) applied Pedroni cointegration tests and Dumitrescu-Hurlin causality tests to examine the link between oil prices and macroeconomic indicators across GCC countries from 2005 to 2015, reporting significant positive relationships with exchange rates, gold prices and stock indices. Alredany (2018) combined regression analysis with principal-component analysis for the period 1986-2010 and found that both OPEC quotas and the number of active drilling rigs exert a strong upward influence on crude-oil prices, whereas a dummy variable for the Gulf War has the opposite effect. Chatziantoniou et al. (2021) employed a time-varying parameter VAR covering 1990-2019 and concluded that financial factors dominate fundamental ones in explaining oil-price volatility. Chevillon and Rifflart (2009), using an error-correction model for 1989-2005, showed that OPEC quotas push prices higher, while OECD inventories pull them lower. Cologni and Manera (2011) relied on a partial-equilibrium model to study small exporting countries between 1995 and 2010; their results indicate that global oil demand shapes production decisions, whereas real-price changes are statistically insignificant. Diaz-Rainey et al. (2017) investigated speculative activity in physical markets with Bai–Perron structural-break tests, finding that inventories depress prices before a speculative phase and lift them during it. Dutta et al. (2020) employed a DCC-GARCH model during the COVID-19 period to analyse the relationship between oil, gold and Bitcoin, highlighting gold's safe-haven role. Liu et al. (2016), using a structural VAR with sign restrictions, attributed about 70 percent of price variation to demand from China and the United States. Madathil et al. (2021) linked oil prices with governance quality and corruption in oil-rich economies from 2000 to 2019, showing that higher prices coincide with both rising GDP and increased corruption. Ozcan (2015) examined oil demand in twenty OECD countries for 1980-2011 and reported positive income elasticity alongside negative price elasticity. Ben Salem et al. (2022) applied ARDL and NARDL models to daily data for 2003-2021, finding that gold prices and futures support higher oil prices, whereas the US dollar index and COVID-19 case counts push them lower. Collectively, these studies underscore the multifaceted drivers of oil-price dynamics. Exchange rates, OPEC quotas and financial speculation consistently emerge as significant determinants, while political uncertainty and financial-market variables also play an important role. Despite this breadth, the long-run implications of climate policy, renewable-energy transitions and innovation in oil-consuming industries remain understudied. Future research would benefit from examining institutional quality, governance and corruption to gain a fuller understanding of oil-price behaviour in resource-dependent economies.

RESEARCH HYPOTHESES

This study investigates three central hypotheses, focusing on the most recent data from the period 2000 to 2023. The selection of this timeframe was motivated by the aim to base the analysis on up-to-date and policy-relevant insights, including the impact of the COVID-19 pandemic. Employing this contemporary scope enables the examination of the latest trends and structural changes in the global oil market, thereby enhancing the relevance of the findings for decision-makers in the fields of resource management and economic energy policy.

Drawing on a thorough review of the relevant literature, the study formulates three hypotheses addressing key factors that influence global oil prices. The first hypothesis examines the effect of OPEC production quotas on oil price formation. The second hypothesis explores the relationship between growth in industrial production and GDP of leading global economies and oil price dynamics. The third hypothesis assesses whether a higher degree of liberalization in the global oil market contributes to lowering international oil prices. Each hypothesis is elaborated below.

H1: Reductions in production quotas set by OPEC have a statistically significant and positive impact on global oil prices

OPEC's production quotas are a pivotal instrument in shaping global oil prices. Acting as a coordinated supply-side mechanism, quotas allow OPEC to reduce overall market supply, thereby increasing prices in accordance with the law of supply and demand. By restricting output, OPEC mitigates oversupply and price collapses, reinforcing its role as a stabilizing force in the oil market. Historically, decisions to reduce production have often been followed by sharp price increases, while expansions of quotas have resulted in falling prices, confirming the theoretical expectations of cartel behavior in oligopolistic markets. This dynamic underscores the relevance of quota policies not only for OPEC members' fiscal stability but also for broader global energy security. Stable oil prices foster greater certainty in national budget planning and long-term energy investment, particularly in the development of alternative energy sources.

H2: Increases in industrial production and GDP growth in major global economies have a statistically significant and positive impact on global oil prices.

The expansion of industrial output and GDP in major world economies leads to a significant increase in global oil demand, which in turn drives up oil prices. This relationship is rooted in the fact that economic growth amplifies demand for energy across sectors such as manufacturing, transportation, and logistics. In partial equilibrium models, where demand surges against a relatively inelastic short-term oil supply, the result is upward pressure on prices. Industrialized economies, such as the United States, China, and the European Union, which are key global oil consumers, drive this demand, making their economic trajectories crucial for understanding oil price trends. While global GDP includes many smaller economies with limited oil demand, the focus on leading economies is justified by their dominant role in global energy consumption and their disproportionate influence on price formation in international oil markets.

H3: A higher level of liberalization in international oil trade has a statistically significant impact on reducing global oil prices.

The third hypothesis is grounded in the principles of international trade and market competition theory. Greater market openness through the reduction or elimination of trade barriers such as tariffs and quotas facilitates the free flow of oil, increases global supply, and stimulates competition. Liberalized oil markets reduce monopolistic constraints and improve allocation efficiency. As more producers enter the market and barriers are removed, operational and logistical costs decline, leading to more competitive pricing. According to economic theory, an increase in competition and supply should result in lower prices, assuming demand does not outpace the supply increase. Moreover, liberalization curtails the ability of dominant firms or cartels to manipulate market conditions, resulting in more stable and affordable energy prices for consumers and industries, while also encouraging broader economic growth.

To empirically test the proposed hypotheses, the study relies on data from publicly available and authoritative databases. Oil price data were obtained from the U.S. Energy Information Administration and the Federal Reserve Economic Data. Production quotas and market concentration data (measured by the Herfindahl-Hirschman Index) were sourced from the Organization of the Petroleum Exporting Countries. Indicators related to industrial production as a share of GDP, as well as oil trade openness, were collected from the World Bank database. This multi-source approach ensures a comprehensive and reliable dataset for capturing the key drivers of global oil market dynamics.

GLOBAL OIL PRICE MODEL

This section defines the analytical framework used to model global oil prices, aiming to elucidate the complex interactions among supply-side, demand-side, and geopolitical factors that influence price formation in international oil markets. Based on a comprehensive review of existing literature, the study identifies the key variables frequently employed in global oil pricing models and the methodological approaches used to assess their impact. The variables affecting oil prices are commonly categorized into three groups: oil supply, oil demand, and geopolitical factors.

The supply side is primarily shaped by global oil production, which encompasses output from both OPEC and non-OPEC countries. A critical instrument in this context is the set of production quotas imposed by OPEC, which serve as a regulatory mechanism for market supply. Additionally, international trade liberalization can significantly influence the supply side. Higher degrees of trade openness allow for greater oil flow across borders, increasing global supply and potentially reducing prices. The demand side is closely tied to global economic growth, especially the gross domestic product of major economies such as the United States, China, and the European Union. As these economies expand, their demand for energy, including oil, rises due to increased industrial production, transportation needs, and other oil-dependent sectors. Industrial activity, therefore, serves as a strong proxy for global oil demand. Geopolitical factors also exert considerable influence over oil prices. OPEC's decisions on production quotas made during regular meetings can cause immediate shifts in oil prices. These interventions often aim to balance supply and demand and stabilize markets, though they may also lead to price increases depending on whether production is cut or raised.

In this model, the dependent variable is defined as the average global oil price, calculated as the arithmetic mean of three benchmark indices: West Texas Intermediate (WTI), Brent, and Dubai. This composite variable allows for a balanced representation of global price movements while mitigating regional biases inherent in any single index. WTI reflects U.S. market dynamics, Brent is the primary reference for European trade, and Dubai serves as a key price point for Middle Eastern crude. By averaging the three, the model ensures a more comprehensive analysis of global oil pricing trends.

The independent variables are structured to capture both supply-side and demand-side influences. These variables were carefully selected to reflect key macroeconomic, trade-related, and exogenous shocks affecting oil markets. The variables are defined as follows:

1. **OPEC Quotas:** This supply-side variable captures oil production levels of OPEC member states. It is measured in thousands of barrels per day (1,000 b/d), as reported in the official OPEC data. Changes in quotas are expected to have a direct impact on global supply, and thus on oil prices.
2. **Non-OPEC Production:** Also on the supply side, this variable reflects oil production from countries outside of OPEC. It is measured in thousands of barrels per day (1,000 b/d), in line with international energy reporting standards. Variations in their output affect global supply levels and oil price movements.
3. **Industrial Production:** Positioned on the demand side, this variable reflects the level of industrial activity worldwide, measured as industry (including construction), value added as a percentage of GDP. As production rises, so does the demand for energy, exerting upward pressure on prices.
4. **Market Openness:** This supply-side indicator measures oil-market openness, calculated as the sum of crude oil imports and exports, measured in thousands of barrels per day (1,000 b/d), and divided by gross domestic product (in constant 2015 US dollars). A higher ratio signals a more liberalized oil trade regime, widening access to international supply channels and thereby exerting downward pressure on prices.
5. **Global Shock 2001:** This demand-side dummy variable captures the immediate and short-term effects of the geopolitical and economic uncertainty following the 9/11 attacks in 2001. The aftermath of the terrorist attacks led to heightened risk aversion, reduced global economic activity, and disruptions in transportation, all of which negatively influenced oil demand and, consequently, oil prices. The variable takes the value of 1 for the years 2001 and 2002, reflecting the period of greatest economic disruption and uncertainty.
6. **COVID-19 Dummy:** This demand-side variable captures the economic shock caused by the COVID-19 pandemic. The years 2020 and 2021 were marked by steep declines in industrial activity and transportation, resulting in a drastic drop in oil demand and prices. The variable takes the value of 1 for the years 2020 and 2021, and 0 otherwise, to reflect the period of most severe pandemic-induced disruption.

In this study, the Herfindahl-Hirschman Index was calculated for global oil production as a means of assessing market concentration and the degree of competition among oil producers. The HHI is a widely used metric in industrial organization and competition policy, providing a quantitative measure of market structure. A higher HHI value indicates a greater level of concentration and thus lower competition, whereas a lower HHI value reflects more diversified and competitive market conditions. By employing the HHI, the study examines how market concentration influences oil prices and how monopolistic or oligopolistic structures may contribute to price fluctuations. In oil markets, where supply is often dominated by a limited number of key producers, understanding the level of concentration is essential for identifying potential market power and related risks. According to Herfindahl and Hirschman (1950), the HHI is calculated as the sum of the squares of the market shares of all firms within the industry. It is particularly useful in evaluating both structural dominance and competitive balance within sectors such as the oil industry. The HHI ranges from 0 to 10,000: Values closer to 0 indicate a highly competitive and diversified market, and Values closer to 10,000 suggest a highly concentrated market, potentially dominated by a few large producers.

Mathematical Expression of HHI:

$$HHI = \sum_{i=1}^{n} s_i^2 \quad (1)$$

Where:
- s_i = market share of firm iii (expressed as a decimal or percentage),
- n= total number of firms in the industry.

The application of the HHI in this research provides valuable insights into the structural characteristics of the global oil market and supports the analysis of how concentration levels may affect oil price behavior and volatility, especially under conditions of supply shocks or coordinated production limits by dominant producers such as OPEC.

RESULTS

Before presenting the research results, the following table provides the calculated Herfindahl-Hirschman Index for global oil production, illustrating the level of market concentration and competition among producers.

Table 1. HHI of Global Oil Production

HHI All countries		HHI OPEC		HHI OPEC+	
2000	535.254	2000	1947.556	2000	3754.732
2001	541.127	2001	1542.56	2001	2966.685
2002	541.606	2002	1420.442	2002	2924.852
2003	572.547	2003	1508.964	2003	3062.587
2004	572.176	2004	1623.611	2004	3246.608
2005	582.430	2005	1671.513	2005	3316.055
2006	580.364	2006	1681.548	2006	3384.751
2007	577.493	2007	1655.257	2007	3387.745
2008	579.291	2008	1694.927	2008	3405.609
2009	580.870	2009	1587.89	2009	3345.682
2010	583.394	2010	1590.151	2010	3353.293
2011	622.996	2011	1621.894	2011	3323.527
2012	635.087	2012	1719.196	2012	3409.627
2013	654.289	2013	1664.406	2013	3330.146
2014	681.73	2014	1598.658	2014	3184.756
2015	697.678	2015	1620.556	2015	3155.531
2016	705.596	2016	1708.074	2016	3288.096
2017	708.490	2017	1701.088	2017	3273.853
2018	754.270	2018	1673.056	2018	3182.951
2019	793.731	2019	1603.901	2019	3047.485
2020	799.883	2020	1500.486	2020	2875.607
2021	793.459	2021	1546.35	2021	2954.567
2022	824.385	2022	1615.595	2022	2970.833
2023	822.316	2023	1574.227	2023	2894.855

Source: Author's calculation

The table above presents an overview of the Herfindahl-Hirschman Index for global oil production from 2000 to 2023, with a particular focus on three categories: all countries, OPEC, and OPEC+. The HHI values for all countries show a gradual increase over time, indicating a slight rise in market concentration within the global oil industry. At the beginning of the observed period, the HHI stood at 535.254, rising to 822.316 by 2023. Although this trend suggests a growing concentration, the values remain below the threshold of 1,500, which, according to industry standards, corresponds to a low to moderately concentrated market. In the case of OPEC, the HHI values show a notable decline, dropping from 1,947.556 in 2000 to 1,574.227 in 2023. This decline indicates a reduction in internal concentration within OPEC, suggesting that production may be becoming more evenly distributed among its member states. While OPEC continues to play a pivotal role in the global oil market, these figures imply a less concentrated internal structure over time.

As for OPEC+, the HHI values remain high throughout the entire period, reflecting a more concentrated structure among these countries. Although the concentration decreased from 3,754.732 in 2000 to 2,894.855 in 2023, OPEC+ still exhibits substantially higher levels of concentration compared to the other two categories. This indicates that a small number of leading OPEC+ producers continue to dominate global oil production, maintaining a strong influence over global supply dynamics. The data suggest that the global oil industry remains relatively competitive, despite a mild increase in concentration. The reduction in HHI values within OPEC and OPEC+ also points to the growing role of non-member producers, contributing to a more diverse global oil supply landscape.

These shifts in concentration do more than describe the market; they raise the central empirical question of the study. If production is becoming less concentrated inside OPEC and OPEC+, yet remains moderately concentrated worldwide, can such structural changes, together with other forces on the supply and demand sides, move the average world oil price? To investigate this link, the research puts forward a series of testable hypotheses and estimates a multiple regression model that includes the main explanatory variables. Each hypothesis is evaluated by examining the statistical significance and the sign of its coefficient. Before turning to the results, Table 2 presents descriptive statistics for every variable in the model, showing their means, standard deviations, minima, and maxima; this snapshot clarifies the structure of the data used in the empirical analysis.

Table 2. Descriptive Statistics of Variables

Variable	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Average reference oil price	24	4.068	0.466	3.194	4.653
OPEC quotas	24	10.233	0.072	10.057	10.333
non-OPEC production volumes	24	9.654	0.084	9.406	9.723
Market openness	24	-15.898	0.168	-16.171	-15.639
Industrial production	24	3.297	0.024	3.257	3.334
COVID-19 (dummy variable)	24	0.083	0.282	0	1
Global Shift 2001	24	0.083	0.282	0	1

Source: Author's calculation

The hypotheses formulated in this research were tested using a multiple regression model that incorporates key supply-side and demand-side variables affecting the average global oil price. Hypothesis testing was conducted by evaluating the statistical significance of the regression coefficients and the direction of influence of each independent variable on the dependent variable. Before presenting the detailed hypothesis testing results, the descriptive statistics of the main variables used in the model are provided below. These statistics offer an overview of the data characteristics, including mean, standard deviation, minimum, and maximum values for each variable, thereby enabling a better understanding of the underlying structure and distribution of the dataset used in the empirical analysis.

Logarithmic transformations were applied in the model to establish a more linear relationship between the dependent and independent variables, thereby enhancing the model's interpretability and statistical robustness. This transformation reduces the variability of the data, mitigates the influence of outliers, and allows the estimated coefficients to be interpreted as elasticities, i.e., percentage changes. In doing so, the model provides clearer insights into the nature and strength of relationships between variables, an essential component of sound economic analysis and informed policy-making.

After examining the basic descriptive characteristics of the dataset, the study proceeds with the analysis of a multiple linear regression model. The general form of the model is presented as follows:

$$ln(Average\ Oil\ Price)_t = \alpha + \beta_1 ln(OPECQ_t) + \beta_2 ln(NONOPEC_t) + \beta_3 ln(OPEN_t) + \beta_4 ln(IND_t) + \delta_1 GS2001_t + \delta_2 COVID_t + \varepsilon_t \quad (2)$$

Where:

- $ln(Average\ Oil\ Price)_t$ is the log-transformed dependent variable, representing the average benchmark price based on WTI, Brent, and Dubai indices.
- α is the intercept (constant term).
- $ln(OPECQ_t)$ is natural log of OPEC production quotas (thousands of barrels per day); β_1 is its elasticity.
- $ln(NONOPEC_t)$ is natural log of global crude oil production outside OPEC (thousands of barrels per day); β_2 is the corresponding elasticity.
- $ln(OPEN_t)$ is natural log of the global oil-trade openness ratio, defined as (world crude oil imports + world crude oil exports /world GDP); β_3 is its elasticity.
- $ln(IND_t)$ is natural log of global industrial production, measured as an index of world industrial output; β_4 is its elasticity.
- $GS2001_t$ is dummy variable equal to 1 in 2001–2002, 0 otherwise; δ_1 is its semi-elasticity.
- $COVID_t$ is dummy variable equal to 1 in 2020–2021, 0 otherwise; δ_2 is its semi-elasticity.
- ε_t is error term.

Based on the model specified above, econometric estimation was performed. The estimated coefficients, their standard errors and the tests of overall model significance (F-statistic and robust Wald test) are reported in Table 3.

Table 3. Estimated Regression Model with Oil Price as the Dependent Variable

Dependent Variable: Average Oil Price				
Variables	**OLS**	**Newey-West**	**Bootstrap (Replications 3,070)**	**Bootstrap (Replications 2,314)**
OPEC Quotas	**-1.592*** **(.762)**	**-1.592*** **(.729)**	**-1.592*** **(.804)**	**-1.592*** **(.804)**
non-OPEC production volumes	**2.308***** **(.546)**	**2.308***** **(.593)**	2.308 (1.403)	2.308 (1.500)
Market Openness	**-1.625***** **(.243)**	**-1.625***** **(.339)**	**-1.625***** **(.353)**	**-1.625***** **(.348)**
Industrial Production	**12.062***** **(1.463)**	**12.062***** **(1.367)**	**12.062***** **(1.648)**	**12.062***** **(1.658)**
COVID-19	**-0.369**** **(.156)**	**-0.369*** **(.181)**	**-0.369*** **(.208)**	**-0.369*** **(.207)**

Dependent Variable: Average Oil Price				
Global Shift 2001	-0.181 (.153)	-0.181 (.140)	-0.181 (.290)	-0.181 (.302)
Number of Observations	**24**	**24**	**24**	**24**
F-statistic	**35.77 (p < 0.001)**	**144.75 (p < 0.001)**	**Wald chi2(6) = 387.94 (p < 0.001)**	**Wald chi2(6) = 371.92 (p < 0.001)**
VIF	**2.12**			

Source: Author's calculation

*Note: Coefficients marked with *** (p < 0.01) are statistically significant at the 1% level, ** (p < 0.05) at the 5% level, and * (p < 0.10) at the 10% level. Standard errors are shown in parentheses.*

To validate the assumptions of the regression model, several diagnostic tests were conducted. The Durbin-Watson test suggested a potential presence of positive autocorrelation (d = 1.27), while the Breusch-Pagan test (p = 0.944) and the Skewness/Kurtosis normality test (p = 0.424) confirmed the absence of heteroskedasticity and non-normality of residuals. In response to the presence of autocorrelation, a Newey-West estimator was employed to obtain robust standard errors. Furthermore, Bootstrap methods with 3,070 and 2,314 replications were used to strengthen the robustness of inference, particularly given the small sample size and to account for possible distributional concerns. The results remained largely consistent across all specifications, confirming the overall stability and robustness of the estimated coefficients. However, it is noteworthy that the coefficient for non-OPEC production volumes, while statistically significant in the OLS and Newey-West models, loses significance under the Bootstrap estimators, which may indicate sensitivity to sampling variability for this particular variable. Accordingly, overall model adequacy is evaluated using the F-statistic and the robust Wald test, both of which indicate strong joint significance. This stability is confirmed across the Ordinary Least Squares, Newey-West adjusted regression, and both bootstrap specifications. The high and statistically significant F-statistics and Wald chi-square values across all versions of the model further reinforce the robustness and reliability of the estimated coefficients. Multicollinearity is not considered a significant concern in this model, as the mean variance inflation factor (VIF) is 2.12, well below the commonly accepted threshold of 5. This indicates that linear dependencies among the explanatory variables are limited and do not materially distort the estimated coefficients.

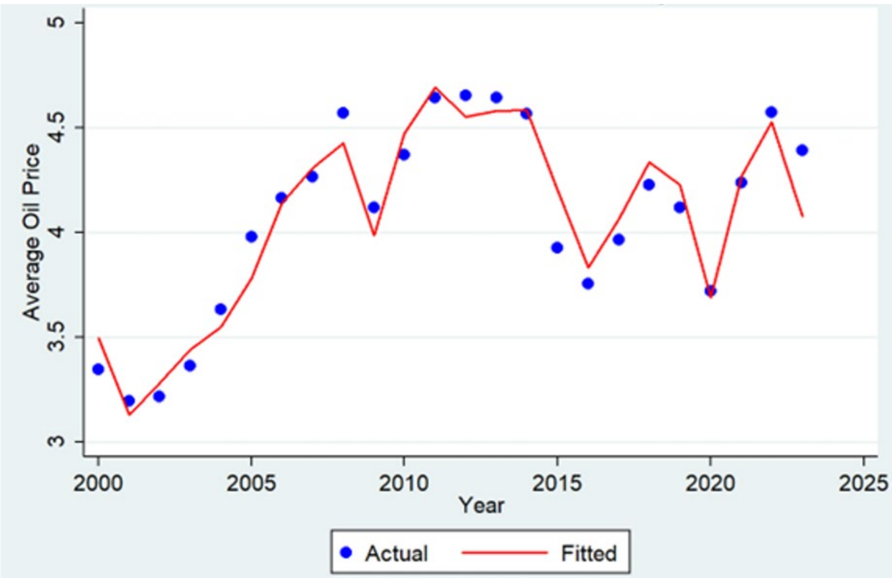

Figure 1. Comparison of actual and predicted values

Source: Author's calculation

To further validate the regression model and visually assess its fit, a comparison between the actual and predicted values of the dependent variable was conducted. The scatter plot of the actual average oil prices and the fitted values derived from the model demonstrate a close alignment, indicating that the model effectively captures the overall trend and fluctuations in the data over time.

As shown in Figure 1, the fitted values closely follow the trajectory of the actual values throughout the observed period, with particularly strong correspondence during periods of major market shifts. Minor discrepancies appear during global shocks, such as the COVID-19 pandemic, underscoring the relevance of incorporating dummy variables to account for such external disturbances. This visual alignment supports the statistical evidence of the model's robustness and its ability to explain variations in the dependent variable.

DISCUSSION

This study analyzed the influence of OPEC-mandated production quotas and other relevant factors on global oil prices. The focus was placed on testing several key hypotheses using a multiple linear regression model and additional statistical tests to assess the significance and impact of these variables.

To validate the key assumptions of the regression model, several diagnostic tests were performed. The Durbin–Watson statistic was used to assess autocorrelation and indicated a potential presence of positive autocorrelation, justifying the application of the Newey–West estimator for robust standard errors. The Breusch–Pagan test confirmed homoskedasticity, while the Skewness/Kurtosis test for normality showed that the residuals follow a normal distribution. These results support the use of OLS and its robust variants in the analysis.

Hypothesis 1 was tested by including the OPEC Quotas variable in the regression model. The results showed a statistically significant negative effect of this variable on global oil prices. Specifically, a one percent increase in OPEC production quotas leads to a 1.59% decrease in the average reference price of oil. Since in the model OPEC quotas are operationalized as actual production volumes (measured in 1,000 barrels per day), the negative coefficient aligns with economic theory: higher quotas increase global supply and reduce oil prices. Therefore, the empirical findings support the expected behavior of a supply-restricting cartel, whereby reductions in quotas lead to upward price pressure. This result was consistently observed across all four model specifications (OLS, Newey-West, and two Bootstrap models), strengthening the robustness of the findings. This finding supports the theoretical framework of supply and demand, where an increase in supply (due to increased quotas) leads to a price decrease. It aligns with numerous previous studies (e.g., Alredany, 2018; Chevillon & Rifflart, 2009; Mercure et al., 2021) that confirm OPEC's influential role in stabilizing oil markets through supply regulation. However, the result contradicts the findings of Colgan (2014), who argued that OPEC's impact on oil prices is statistically insignificant due to the lack of quota compliance among member states. Despite differing interpretations, the significant negative coefficient in this model reaffirms that OPEC quotas remain a critical mechanism for influencing global oil supply and prices. Hence, Hypothesis 1 is confirmed, as reductions in OPEC quotas (i.e., lower production) are associated with higher global oil prices, in line with the stated hypothesis.

Hypothesis 2 was tested by introducing the Industrial Production variable, representing the demand side of the market. This variable reflects the level of economic activity and the need for energy within the industrial sector. The analysis revealed that a one percent increase in industrial production leads to a 12.06% increase in oil prices, indicating a strong and statistically significant positive relationship across all four model specifications (OLS, Newey-West, and both Bootstrap models). This confirms the hypothesis that greater industrial activity boosts demand, subsequently pushing prices higher. The robustness and consistency of this finding underscore the central role of economic activity in shaping oil market dynamics. These results are consistent with theoretical expectations and prior literature (Mercure et al., 2021; Jibril et al., 2020; Yoshino & Victoriia, 2019), which show that demand-side pressures during economic expansion tend to elevate energy prices.

Hypothesis 3 was tested by incorporating the Market Openness variable, approximating the degree of trade liberalization in global oil markets. The regression results show a statistically significant negative relationship between market openness and oil prices across all four model specifications (OLS, Newey-West, and both Bootstrap models). A one percent increase in openness measured by the ratio of oil trade (exports + imports) to GDP results in a 1.62% decrease in the average oil price. This supports the idea that greater trade liberalization and reduced trade barriers increase competition and supply, leading to lower global oil prices. These findings are in line with theoretical models (Jibril et al., 2020; Moshiri & Kheirandish, 2024; Scheitrum & Revoredo-Giha, 2018), which argue that increased global supply without a proportional increase in demand drives prices down due to improved resource allocation and enhanced competition. Therefore, Hypothesis 3 is confirmed.

The variable representing non-OPEC production volumes was included in the model to account for the influence of oil supply from countries outside the OPEC framework. The coefficient for this variable is positive and statistically significant in the OLS and Newey-West models, suggesting that increases in non-OPEC production are associated with higher global oil prices. Specifically, a one percent increase in non-OPEC output corresponds to an average 2.31% rise in the reference oil price, holding other factors constant. However, under the Bootstrap models with 3,070 and 2,314 replications, the coefficient loses statistical significance, indicating a possible sensitivity of this variable to sampling variability and a reduced robustness of this relationship under alternative inference techniques. This may reflect the more fragmented and less coordinated nature of non-OPEC supply behavior, as well as the influence of external shocks and strategic responses that differ by country. Despite this inconsistency, the direction of the coefficient remains the same across all models, which may still suggest some underlying structural relationship between non-OPEC output and price dynamics, albeit less stable than that observed for OPEC quotas or other key demand-side variables.

In addition to the main explanatory variables used to test the three hypotheses, the COVID-19 dummy variable was included in the model to capture the demand-side shock caused by the pandemic. The variable takes the value of 1 for the years 2020 and 2021, reflecting the peak period of global economic disruption. Across all four model specifications (OLS, Newey-West, and both Bootstrap models), the coefficient for COVID-19 is consistently negative and statistically significant, indicating that the pandemic exerted substantial downward pressure on oil prices. Specifically, the presence of COVID-19 is associated with an average decline of approximately 0.369 units in the average oil price. This result confirms the expected impact of the pandemic on global energy demand, particularly through reductions in industrial output, transport, and trade. The finding is consistent with prior research (e.g., Narayan, 2020; Devpura & Narayan, 2020), which documented the severe economic and energy-market repercussions of the COVID-19 crisis. Additionally, the model includes the Global Shift 2001 dummy variable to account for the immediate and short-term market disruptions following the geopolitical and economic instability in 2001. This variable takes the value of 1 for the years 2001 and 2002, reflecting the period of greatest uncertainty. The estimated coefficient is negative across all model specifications, suggesting a reduction in oil prices during that period; however, the result is not statistically significant. This may indicate that while global uncertainty in the early 2000s had an impact on oil markets, the effect was either short-lived or outweighed by other concurrent market factors.

The study also calculated the Herfindahl-Hirschman Index to assess the level of market concentration in global oil production. The HHI values were analyzed descriptively and not included directly in the regression model. Nevertheless, the observed trends provide important structural context. The slight increase in the global HHI over time suggests a growing concentration in oil production at the international level, while internal concentration within

OPEC and OPEC+ shows a moderate decline. These structural changes are relevant when interpreting the regression results. Specifically, the negative and statistically significant coefficient for the Market Openness variable implies that greater trade integration and competitive dynamics tend to reduce oil prices. Although HHI was not used as an explanatory variable, the descriptive trend of rising global concentration helps frame the broader market conditions under which openness exerts its influence. Thus, while the relationship is not modeled directly, the HHI analysis complements the regression findings by offering a structural backdrop against which demand and supply variables operate.

CONCLUSION

The analysis of the impact of the Organization of the Petroleum Exporting Countries and other relevant factors on global oil prices reveals a complex network of interrelated influences that shape the global oil market. Supply and demand forces are fundamental in determining oil prices. Prices respond to supply and demand shocks, economic growth, inflation, and currency fluctuations. Technological advances, such as hydraulic fracturing and horizontal drilling, have significantly increased supply, while economic growth in countries like China and India has driven global demand upward. Geopolitical tensions, conflicts, and sanctions directly affect oil supply and price volatility. For example, sanctions against Iran or political instability in the Middle East often result in price spikes. Additionally, macroeconomic factors, including global GDP growth, inflation, and exchange rate volatility, play an important role in price fluctuations. Technology has made it possible to access previously unreachable reserves, reduce production costs, and improve energy efficiency. These advancements, coupled with the transition toward renewable energy sources, are gradually transforming oil market dynamics.

The empirical findings of this study demonstrate that OPEC production quotas have a statistically significant and negative impact on global oil prices. Specifically, a one percent reduction in quotas leads to a 1.59% increase in oil prices. Based on the descriptive analysis and literature review, OPEC's role as a cartel is central to supply control and price stabilization. The organization operates through coordinated production quota decisions, aiming to balance supply and demand and maintain favorable price levels amid shifting global conditions. The literature review emphasizes several important conclusions: First, geopolitical factors such as crises and conflicts in oil-rich regions significantly affect price volatility. Second, technological progress, particularly among non-OPEC producers, has expanded global supply, reducing dependence on OPEC and increasing competition. The results also show that increased industrial production, especially in the world's largest economies, positively affects demand and price levels. A one percent rise in global industrial output corresponds to a 12.06% increase in oil prices, confirming the strong link between economic activity and oil demand. Moreover, greater market openness contributes to lower oil prices by intensifying competition. An increase in oil trade openness by one percent reduces oil prices by 1.62%, indicating the significant downward pressure that liberalized markets and technological advancement exert on prices. Additionally, the variable representing Non-OPEC production volumes showed a positive and statistically significant coefficient in both the OLS and Newey-West models, indicating that increased output from non-OPEC countries is associated with higher global oil prices. This result may reflect supply-side dynamics where greater production from competitive, non-cartelized sources coincides with rising global demand or anticipatory behavior in futures markets. However, in both Bootstrap models, the coefficient turns negative and statistically insignificant, suggesting that the relationship may be sensitive to distributional assumptions or sampling variability. This inconsistency underscores the heterogeneous nature of non-OPEC producers and the lack of coordinated supply mechanisms, which limits their collective influence on global oil price stabilization.

Synthesis from the literature further highlights the susceptibility of oil markets to economic shocks, geopolitical risks, and technological changes, particularly during the COVID-19 pandemic, which triggered a dramatic decline in global oil demand and a sharp price drop. Furthermore, early 2000s geopolitical and economic shifts did not exhibit a statistically significant effect on global oil prices in the estimated models.

Although this study makes several important contributions, it is not without limitations. The analysis in this study begins in the year 2000 and deliberately excludes the 2008 global financial crisis to allow a focused assessment of more recent structural shifts, particularly the COVID-19 pandemic. While both the COVID-19 and 2001 events are accounted for as structural shocks through dummy variables, the model treats these events as discrete and time-bound. Future research should consider methodologies that allow for a dynamic understanding of such shocks, for example, by employing time-varying parameter models, structural break tests, or rolling regressions to assess how the impact of the pandemic evolves over time, particularly in terms of demand elasticity and supply adjustment. In addition, although this study recognizes the broader relevance of climate policy, renewable energy expansion, and institutional factors, future analyses could benefit from framing these themes into more targeted research questions. For instance: How do long-term decarbonization strategies influence the responsiveness of oil-exporting countries? To what extent does institutional quality mediate the price effects of external shocks? How does the pace of renewable energy adoption reshape expectations in oil futures markets? Addressing such questions would contribute to a more nuanced and policy-relevant understanding of how structural changes interact with traditional market fundamentals in shaping global oil prices.

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