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AN EMPIRICAL ANALYSIS OF SUPPLY AND DEMAND FACTORS INFLUENCING GLOBAL OIL PRICES: A PANEL DATA APPROACH

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Abstract: This study examines the factors that impact global oil prices, focusing on the relationship between supply and demand in international markets. The authors used an econometric panel methodology to identify the primary factors influencing global oil prices, using Brent crude oil prices as the dependent variable. The study also considered alternative measures, such as Dubai and West Texas Intermediate (WTI) prices, as well as a composite global price index derived from the average of WTI, Dubai, and Brent prices, to ensure the robustness of the findings. The study found that key factors influencing global oil prices remained consistent across different dependent variables introduced into the model. The research emphasizes the critical role of supply and demand dynamics as the main drivers shaping global oil prices. On the supply side, variables such as oil reserves, international oil trade, and the number of active oil rigs were considered. The results indicated that an increase in active oil rigs is associated with increased oil prices, while an increase in international oil trade leads to price reductions. When oil prices rise, active oil rigs often increase, but with a specific time lag. This rig increase can further drive up oil prices, particularly when the market expects continued price growth or when investments in new rigs are financed by anticipated higher revenues from oil sales. Increased international trade in oil leads to a more excellent supply of oil in the global market, which drives down global oil prices. Although oil reserves showed a positive coefficient, they were marginally significant, suggesting a potential upward pressure on prices when reserves increase. This positive relationship between oil reserves and prices may reflect market perceptions of future supply constraints, where increased reserves signal potential future scarcity rather than immediate availability, thereby exerting upward pressure on prices due to speculative behavior and strategic stockpiling. On the demand side, industrial growth was a critical factor that significantly drove oil prices higher. At the same time, renewable energy consumption had a statistically significant adverse impact, reducing global oil demand and lowering oil prices. The study also examined the impact of major global events, including the COVID-19 pandemic and the effects of the Global Financial Crisis. It revealed that the COVID-19 pandemic had a statistically significant negative impact on oil prices due to worldwide lockdowns and economic slowdowns. However, the Global Financial Crisis did not exhibit statistical significance in the model using WTI prices, though it still negatively affected all models. The study employed various panel data regression techniques, including pooled, fixed effects (FE), and random effects (RE) models. Diagnostic tests for heteroskedasticity and autocorrelation were conducted, leading to the application of Robust Hausman tests that identified the fixed effects model as the most appropriate for this analysis. Moreover, the study used Driscoll-Kraay standard errors to correct for heteroskedasticity, autocorrelation, and cross-sectional dependence, which reinforced the fixed-effects model's validity. The key findings highlighted the importance of supply and demand as pivotal factors influencing global oil prices.

Keywords: oil prices, international trade, supply and demand, panel data, COVID-19, Global Financial Crisis
Field: Social sciences

1. INTRODUCTION

A complex interplay of global supply and demand factors impacts oil prices. These dynamics significantly influence oil prices, as highlighted in various studies. Effiong (2014) notes that oil price shocks can originate from both supply and demand sides in the crude oil market, indicating that supply disruptions do not solely drive oil price fluctuations but can also be caused by demand shocks. Jibril, Chaudhuri, and Mohaddes (2020) further emphasize that while oil supply disruptions have a minor and temporary effect on actual oil prices, specific oil demand and aggregate demand increases can lead to significant and lasting impacts on oil prices. Robays (2016) explores the relationship between macroeconomic uncertainty and oil price volatility, revealing that higher levels of macroeconomic uncertainty, such as volatility in global industrial production, can significantly amplify the sensitivity of oil prices to both demand and supply shocks.

Additionally, Zhu, Su, Guo, and Ren (2016) provide insights into the asymmetric effects of oil price shocks on the Chinese stock market, showing that positive oil supply shocks reduce oil prices while positive demand shocks increase prices. Jin, Zhai, and Zhu (2022) discuss various factors driving oil price increases, including oil production disruptions, unexpected global economic expansion, and expectations

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of future supply shortages, each with different effects on accurate oil prices. Nia and Aminata (2022) elaborate on the short-term effects of oil shocks, emphasizing the impact of oil supply shocks, global demand shocks, and specific oil demand shocks on crude oil prices. These findings collectively highlight the multifaceted nature of oil price determinants and the different impacts that supply and demand shocks can have on global oil prices. Yoshino and Alekhina (2019) contribute to understanding oil price determinants by developing an aggregate supply and demand model for oil to empirically assess the impacts of supply and demand factors on Brent crude oil prices. Ekong and Effiong (2015) further decompose oil price shocks using a Structural Vector Autoregressive (SVAR) model, separating them into oil supply, aggregate demand, and specific oil demand shocks. Mokni (2023) employs detrended cross-correlation analysis to identify supply shocks, aggregate demand shocks, and specific oil demand shocks among global oil prices, shedding light on the different drivers of oil price fluctuations. Understanding these various components of shocks is crucial for a comprehensive analysis of the factors affecting oil prices. Baek (2021) highlights the varied impacts of rising oil prices on external balances, depending on whether they are driven by global oil supply disruptions, economic expansions, or changes in precautionary measures due to future supply risks.

The global oil price is a complex phenomenon influenced by many interconnected factors related to supply and demand dynamics in the international oil market. Benchmarks such as Brent Crude, WTI, Dubai prices, and others play a crucial role in shaping the global economy due to the importance of oil as an essential commodity across various sectors. Studies have highlighted the critical role of oil prices in influencing the energy sector and broader economic activities, with oil price shocks affecting stock markets, real estate markets, and international trade. The complex relationships between oil prices and various economic indicators emphasize the interconnectedness of the global oil market with other sectors of the economy. In addition to Brent, WTI, and Dubai, other oil benchmarks such as the OPEC Reference Basket, Urals, Bonny Light, Mexican Basket, Tapis, and Mars provide standardized pricing and facilitate global trade, ensuring transparency in the oil market.

Based on the earlier text, we can conclude that the balance of supply and demand mainly determines the global oil price. Numerous researchers have explored the factors influencing oil prices on a deeper level, investigating the role of oil reserves (Hamilton and Herrera 2004; Askari and Krichene, 2010; Yoshino and Alekhina, 2019; Van Robays, 2012), production levels (Van Robays, 2012; Nia & Aminata, 2022), active rigs (Khalifa, Caporin, & Hammoudeh, 2017; Ringlund, Rosendahl, & Skjerpen, 2008), the adoption of renewable energy (Fattouh, Poudineh, & West, 2018; Magazzino & Giolli, 2024), trade openness (Majumder, Raghavan, & Vespignani, 2020), exchange rates (Hamilton and Herrera, 2004; Askari and Krichene, 2010; Yoshino and Alekhina, 2019; Jibril, Chaudhuri, & Mohaddes, 2020), technological advancements (Fattouh et al., 2018), industrial growth (Van Robays, 2012; Jibril et al., 2020; Nia & Aminata, 2022; Yoshino & Alekhina, 2019), and global crises like the COVID-19 pandemic and the global financial crisis (Shehzad et al., 2021; Yu, Guo, & Chang, 2022), all of which can significantly shape the dynamics of oil supply and demand.

2. MATERIALS AND METHODS

The methodology for this study involved several steps to ensure the robustness and reliability of the findings regarding the factors influencing global oil prices from 2000 to 2022. We selected this time frame precisely to capture the effects of major global events, including the Global Financial Crisis and the COVID-19 pandemic. We also created artificial dummy variables to account for these events. To begin, we presented descriptive statistics to summarize the key characteristics of the data. We then used pooled OLS, fixed effects (FE), and random effects (RE) models to explore the relationships between the independent variables and global oil prices. The independent variables included Oil Reserves, Oil Production, Active Rigs, Renewable Energy (RE) consumption, Trade Openness, Exchange Rate Fluctuations, Technology, GDP Growth, Industry Output, COVID-19, and the Global Financial Crisis. All variables in this study underwent log transformation to ensure linearity and normalize the distribution, thus facilitating more accurate econometric analysis. This study's "Trade Openness" variable explicitly measures the international oil trade level. Traditionally, trade openness is calculated as the ratio of total imports and exports to GDP. However, this analysis's calculation has been refined to focus only on oil imports and exports. This provides a more precise measure of the extent countries are open to global oil trade flows. The variable "Exchange Rate Fluctuations" represents the fluctuations of the domestic currency in relation to the US dollar. This focus is particularly relevant because oil is predominantly traded globally in US dollars, making exchange rate shifts critical in understanding oil price dynamics. The sample in this analysis includes countries from both developing and developed nations. The number of

observations in the model depends on data availability, as only countries with complete data across all variables were included in the panel analysis using STATA software.

After estimating the pooled FE and RE models, we conducted diagnostic tests to assess the presence of autocorrelation, heteroskedasticity, and cross-sectional dependence. These tests revealed the presence of both heteroskedasticity and autocorrelation within the models. Consequently, we applied the robust Hausman test, which indicated that the fixed effects (FE) model was more appropriate for the analysis than the random effects model. To address these econometric issues, we employed Driscoll-Kraay standard errors. This approach corrected for heteroskedasticity, autocorrelation, and cross-sectional dependence, enhancing the estimates' reliability and ensuring the model's robustness. We sourced data for the study from several vital databases, including the World Bank (WB), the Organization of the Petroleum Exporting Countries (OPEC), the International Energy Agency (IEA), the International Monetary Fund (IMF), and the Federal Reserve Economic Data (FRED). These databases provided comprehensive data on oil-related variables and macroeconomic indicators essential for the analysis. The dependent variable in the analysis was Brent Crude oil prices. In contrast, WTI and Dubai Crude oil prices were introduced as alternative dependent variables to test the robustness of the model. Additionally, we created a new composite variable representing the average prices of Brent, WTI, and Dubai Crude oil, offering a more comprehensive perspective on the factors influencing global oil prices from both supply and demand angles.

3. RESULTS

The summary statistics in Table 1 show the characteristics and variation of the critical variables analyzed in this study. These variables represented supply- and demand-side factors affecting global oil prices. These insights set the stage for the following econometric analysis, which investigated how these supply and demand variables interacted to influence the dynamics of oil prices. The findings of these analyses are presented below.

Table 1. Descriptive statistics of the variables used in the analysis

Variable	Obs	Mean	Std. Dev.	Min	Max
WTIPrice	4,807	4.049	.427	3.254	4.600
BrentPrice	4,807	4.077	.474	3.19	4.718
DubaiPrice	4,807	4.032	.490	.490	4.690
MediaPrice	4,807	4.054	.463	3.192	4.654
OilReserves	2,045	18.191	2.975	11.128	24.471
OilProduction	1,932	11.858	2.863	1.791	17.046
ActiveRigs	917	2.815	1.459	0	7.602
RE	4,242	2.519	1.924	4.892	18.497
TradeOpenness	2,208	11.089	1.924	4.892	18.497
ExchRateFluct	4,519	2.766	2.743	-3.112	22.628
Technology	2,207	-.963	.679	-2.302	0
GDPGrowth	2,366	.478	.306	0	1.342
Industry	3,177	7.065	.993	0	8.063
COVID-19	4,807	.043	.203	0	1
Glob.Finan.Crisis	4,807	.043	.203	0	1

Source: Author's Calculation

This study's variables cover supply and demand factors influencing global oil prices. On the supply side, factors such as oil reserves, oil production, active rigs, trade openness related to oil, and technological advancements reflect the capacity and flow of oil in global markets, impacting availability and production efficiency. On the demand side, factors such as renewable energy consumption, exchange rate fluctuations, GDP growth, industrial output, and significant global events like the COVID-19 pandemic and the Global Financial Crisis drive consumption patterns and economic activity, ultimately shaping the oil demand. These variables offer a comprehensive view of the dynamic interplay between supply and demand in determining global oil price movements.

The regression results for the Brent Crude, WTI, Dubai Crude, and MediaPrice variables are presented in the table below. They utilize pooled OLS, fixed-effects (FE), random-effects (RE) models, and Driscoll-Kraay standard errors.

Table 2. Regression Results for Crude Oil Prices: Pooled OLS, FE, RE, and DK Models

Variable	Pooled Brent crude	FE Brent crude	RE Brent crude	DK Brent crude	DK WTI	DK Dubai	DK MediaPrice
OilReserves	**-.052 *** (.017)**	.099 (.073)	**-.052 *** (.017)**	**.099* (.017)**	**.076** (.034)**	**.093* (.051)**	**.090* (.046)**
OilProduction	.019 (.018)	-.078 (.089)	.019 (.018)	-.078 (.064)	-.068 (.065)	-.080 (.065	-.076 (.065)
ActiveRigs	**.097 *** (.017)**	**.086*** (.028)**	**.097*** (.017)**	**.086*** (.024)**	**.066** (.026)**	**.087** (.024)**	**.080*** (.024)**
RE	-.003 (.009)	**-.135 ** (.067)**	-.003 (.009)	**-.135 ** (.061)**	**-.134** (.050)**	**-.127* (.063)**	**-.132** (.058)**
TradeOpenness	-.018*** (.013)	**-.041** (.017)**	-.018 (.013)	**-.041 ** (.016)**	**-.040*** (.014)**	**-.038** (.015)**	**-.040 ** (.015)**
ExchRateFluct	**-.019** (.007)**	**-.500** (.076)**	**-.019** (.007)**	**-.500** (.115)**	**-.514*** (.096)**	**-.497*** (.115)**	**-.504** (.107)**
Technology	**-.178 *** (.050)**	**-.367*** (.092)**	**-.178*** (.050)**	**-.367*** (.084)**	**-.318*** (.073)**	**-.365*** (.089)**	**-.351*** (.080)**
GDPGrowth	**-.249 *** (.071)**	.186 (.148)	**-.249 *** (.071)**	.186 (.114)	.119 (.111)	.192 (.114)	.167 (.113)
Industry	**.091*** (.030)**	**.600*** (.091)**	**.091*** (.030)**	**.600*** (.128)**	**.588*** (.096)**	**.598*** (.137)**	**.596*** (.119)**
COVID-19	**-.465*** (.149)**	**-.233* (.133)**	**-.465*** (.149)**	**-.233*** (.082)**	**-.224*** (.069)**	**-.212** (.087)**	**-.223*** (.079)**
Glob.Finan Crisis	-.018 (.052)	**-.158 *** (.045)**	-.018 (.052)	**-.158** (.071)**	-.076 (.051)	**-.145 ** (.071)**	**-.127* (.064)**
Obs.	354	354	354	354	354	354	354
MODEL SIG.	F(11,342)= 6.64 Prob = 0.000	F(11,306)= 25.45 Prob = 0.000	F(8,48)= 5.60 Prob = 0.000	F(11, 36)= 1326.12 Prob = 0.000	F(11, 36)= 1911.03 Prob = 0.000	F(11, 36)= 1277.35 Prob = 0.000	F(11, 36)= 1506.91 Prob = 0.000
COEF. OF DETERMINATION	R^2 = 0.176 R^2_{adj}=0.149	within = 0.477 between = 0.004 overall = 0.018	within = 0.482 between = 0.130 overall = 0.257	R^2 = 0.477	R^2 = 0.513	R^2 = 0.467	R^2 = 0.487

Note: Standard errors are given in parentheses. Asterisks indicate the level of significance: *** significance level at 1%, ** significance level at 5%, * significance level at 10%.

Source: Author's Calculation

This study used panel data to analyze the factors influencing global oil prices, focusing on Brent Crude as the dependent variable. The authors conducted multicollinearity diagnostics before the regression analysis to ensure the model's reliability. The calculated Variance Inflation Factor (VIF) values were 2.94, indicating no significant multicollinearity issues in the model. To test the robustness of the model, the authors also altered the dependent variable to include the prices of WTI and Dubai Crude oil. Additionally, they created a new variable representing the average prices of Brent, WTI, and Dubai Crude to provide a comprehensive view of the factors influencing global oil prices from both supply and demand perspectives. Autocorrelation tests were performed across the models, revealing the following results. For Brent Crude, the analysis yielded an F-statistic of 242.153, with a p-value of less than 0.000. WTI showed an F-statistic of 221.120 (p-value = 0.000), while Dubai Crude exhibited a value of 293.592 (p-value = 0.000). Similarly, for the Media Price, the F-statistic was 252.873 (p-value = 0.000). These findings indicate the presence of autocorrelation in all models. Heteroskedasticity tests were conducted using the Modified Wald test for groupwise heteroskedasticity. For Brent Crude, the chi-squared statistic was 7363.31 (p-value = 0.000). WTI yielded a chi-squared statistic of 548.04 (p-value = 0.000), while Dubai Crude showed a value of 8743.58 (p-value = 0.000). Similarly, the Media Price's chi-squared statistic was 5727.87 (p-value = 0.000). These findings confirm the presence of heteroskedasticity in all models. The authors employed the Robust-Hausman test to account for both autocorrelation and heteroscedasticity in the models. This test was used to determine whether the Fixed Effects (FE) or Random Effects (RE) model is more appropriate. The robust version of the Hausman test provides reliable and unbiased parameter estimates, effectively addressing issues of autocorrelation and heteroskedasticity within the model. The results of the Hausman test showed a chi-squared statistic of 62.53 with 11 degrees of freedom (p-value = 0.000), confirming a significant difference between fixed and random effects models. Consequently, the fixed effects model was validated as the most appropriate for this analysis, ensuring that the results are not biased by the underlying heteroskedasticity or autocorrelation. Furthermore, a cross-sectional dependence test was applied using Pesaran's method (2015). The results were as follows: for Brent Crude, CD = 33.006 (p-value = 0.000); for WTI, CD = 32.854 (p-value = 0.000); for Dubai Crude, CD = 33.281 (p-value = 0.000); and for the Media Price, CD = 32.790 (p-value = 0.000). These results indicate significant cross-sectional dependence in all models. Moreover, Driscoll-Kraay standard errors were employed to correct for heteroskedasticity, autocorrelation, and cross-sectional dependence, thereby reinforcing the reliability and validity of the fixed effects model.

4. DISCUSSIONS

The results section's data show the estimated coefficients for models analyzing Brent Crude, WTI, Dubai Crude, and Media Price, revealing consistent relationships between oil prices and supply- and demand-side factors.

• Supply-Side Influences: Oil reserves are consistently positively correlated with oil prices. Increased reserves indicate potential future supply constraints, leading to higher prices due to market speculation and strategic stockpiling. This relationship holds for Brent, WTI, Dubai Crude, and Media Price variables, as confirmed by Driscoll-Kraay estimates. Active oil rigs also significantly impact prices, as there is a delayed increase in rig activity as prices rise, which can further drive prices up when market expectations remain positive. Additionally, increased international oil trade tends to lower prices by expanding global supply and easing upward pressure on prices.

• Demand-Side Influences: Industrial output significantly increases oil prices as higher industrial activity drives greater oil consumption in manufacturing, transportation, and energy production. The consistent positive effect across models highlights the role of industrial demand in shaping oil prices. In contrast, renewable energy consumption and exchange rate fluctuations significantly negatively impact oil prices. The global shift to renewables reduces oil demand, while a stronger U.S. dollar makes oil more expensive for foreign buyers, dampening demand. Exchange rate volatility further depresses prices by creating market uncertainty.

• Technology and Global Shocks: Technological advancements consistently negatively affect oil prices, as they enhance energy efficiency and promote alternatives to oil while lowering production costs and increasing supply. The robustness of this effect across models underscores the role of technology in reducing oil dependence. The COVID-19 pandemic caused a significant drop in oil prices due to global lockdowns and reduced demand in key sectors like transportation and manufacturing. In contrast, the 2008 Global Financial Crisis had a less consistent impact, particularly in the WTI model, where it was not statistically significant. The crisis's delayed effect on oil demand contrasts with the immediate shock caused by COVID-19, which disrupted entire industries. The WTI market's more U.S.-centric nature, supported by strategic reserves and local resilience, likely cushioned its response to the financial crisis.

5. CONCLUSIONS

This study delves into the complex relationship between supply and demand factors that affect global oil prices, focusing on the period from 2000 to 2022. The study utilizes an econometric panel methodology to examine the main influences on Brent Crude oil prices, WTI, and Dubai Crude prices and a composite index of the three to ensure the robustness of the findings. The findings consistently highlight the significant influence of supply and demand factors on oil price changes. On the supply side, the research shows that rising oil reserves consistently correlate with higher oil prices. Increasing reserves may indicate potential future supply constraints, leading to market expectations and upward price pressure. Similarly, the number of active oil rigs correlates positively with oil prices, indicating that delayed increases in rig activity often coincide with rising prices, further pushing them upward as market optimism persists. However, international oil trade expansion tends to lower prices by increasing global supply.

From the demand side, industrial output significantly drives oil prices, as heightened industrial activity increases oil consumption across manufacturing, transportation, and energy production sectors. Conversely, renewable energy consumption exerts downward pressure on oil prices, reflecting the global shift from fossil fuels. Exchange rate fluctuations also impact oil prices, with a stronger U.S. dollar dampening foreign demand, while exchange rate volatility contributes to market uncertainty, further depressing prices. Technological advancements consistently significantly reduce oil prices by promoting energy efficiency, lowering production costs, and increasing supply through innovations in oil extraction and alternative energy sources. The study also highlights the significant impact of the COVID-19 pandemic, which caused a significant drop in oil prices due to global lockdowns and reduced demand from major sectors. However, the Global Financial Crisis 2008 had a less consistent impact on oil prices, particularly in the WTI model, where it was not statistically significant.

The findings provide valuable insights for policymakers and stakeholders who want to understand the complexities of the global oil market and create strategies to improve economic stability and resilience.

The research shows that supply and demand are the main factors influencing global oil prices, a consistent observation across all models using Driscoll-Kraay standard errors. Additionally, the study emphasizes the significant role of international oil trade, which has been overlooked in many previous studies.

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