JEEPO (2024), 7(4), 31-41.

Journal of Energy & Environmental Policy Options

Temporal Dynamics of Oil Demand Elasticities in OECD Economies

Kiumars Nili[a], Younes Asadi[b]

Abstract

This study investigates the long-run income and price elasticities of oil demand in 21 OECD countries, utilizing quarterly data spanning the period from 1980 to 2023. The findings indicate that oil demand is inelastic for both income and prices, suggesting that changes in these variables result in proportionally smaller adjustments in oil consumption. This inelasticity underscores the essential nature of oil in the economies of OECD countries, where demand remains relatively stable despite fluctuations in income levels or oil prices. The cointegration tests conducted in the study reveal that oil price elasticities exhibit instability over time. This instability may reflect shifts in economic structures, technological advancements, energy policies, and global oil market dynamics over the decades. These findings highlight the complexity of understanding oil demand behavior and underscore the importance of considering temporal variability when analyzing the relationship between oil prices, income, and demand. The study provides valuable insights for policymakers and energy market analysts in designing strategies that account for these persistent and evolving demand patterns. The time-varying panel data estimates corroborate these findings, revealing significant variations in income and price elasticities over time, influenced by oil market dynamics and global events. Notably, the sign of oil price elasticities shifted from negative to positive after 2015, a deviation from the traditional law of demand. This unexpected shift is likely attributable to the period of declining oil prices, which may have encouraged increased consumption, investments in oil-dependent industries, or changes in market behavior. The most pronounced positive and statistically significant price elasticity occurred in early 2020, coinciding with the onset of the COVID-19 pandemic. During this time, disruptions in oil supply chains, unprecedented declines in global demand, and price volatility may have contributed to atypical consumer and producer responses, amplifying the sensitivity of oil demand to price changes. These results highlight the dynamic and context-dependent nature of oil demand elasticities, underscoring the importance of considering temporal and situational factors in policy and market analysis. This analysis provides valuable insights into the dynamics of oil demand and underscores the influence of economic and oil market factors on income and price elasticities. By revealing the inelastic nature of oil demand and the temporal variability in elasticities, particularly the unexpected shifts in price elasticity post-2015, the study enhances our understanding of how global events, market dynamics, and economic conditions shape oil consumption patterns. These findings contribute to the broader literature on energy economics and offer critical implications for policymakers and market analysts. They emphasize the need for adaptive strategies that account for evolving demand behavior, especially in the context of volatile oil markets and global economic shifts. This analysis serves as a foundation for designing informed energy policies, managing market uncertainties, and forecasting future oil demand trends.

Keywords: Oil Demand Elasticities, OECD, Income Elasticity, Price Elasticity

JEL Codes: Q41, C23, E21, F64

Received: 09-11-2024 **Revised: 09-12-2024** **Online Published: 25-12-2024**

1. INTRODUCTION

Energy consumption is essential for human welfare and plays a critical role in driving economic growth (Ali & Audi, 2016; Shahbaz et al., 2016; Alabi, 2010; Sharma & Strauss, 2013; Audi & Ali, 2017). Among energy resources, oil is particularly significant due to its widespread use in transportation, industry, and heating (Ali et al., 2021; Hussain & Khan, 2022; Keller, 2022; Ali et al., 2022; Rossi, 2023; Kibritcioglu, 2023; Senturk, 2023; Çiçekçi & Gaygısız, 2023; Audi & Ali, 2023; Ali et al., 2023; Elkamel, 2023; Abdelkawy et al., 2024; Abdelkawy & Al Shammre, 2024; Laniran & Adeleke, 2024; Audi et al., 2024). While global oil demand continues to grow, with developing nations such as China and India emerging as major consumers, the demand dynamics in Organization for Economic Co-operation and Development (OECD) countries present a contrasting trend. This study employs a time-varying framework to estimate the income and price elasticities of oil demand in OECD countries. Over the past four decades, the contribution of OECD countries to global oil demand has declined significantly. In 1980, OECD nations consumed 41,943 kilobarrels per day (kbd) of oil, accounting for 67% of global demand. By 2020, this figure had risen slightly to 42,183 kbd, yet their share of global demand had fallen to 46%, reflecting shifts in

[a] Faculty of Economics and Management, Ferdowsi University of Mashhad, Mashhad, Iran

[b] Faculty of Economics and Management, Ferdowsi University of Mashhad, Mashhad, Iran

global consumption patterns. Several factors have driven this decline in OECD oil demand. One key factor is the increasing adoption of renewable energy sources, which are now more affordable and efficient. This transition has reduced the reliance on oil for electricity generation, contributing to a restructured energy mix. Over the past four decades, the share of oil in the energy mix of OECD countries has decreased from 45.9% to 31.3%. During the same period, the share of natural gas has increased modestly from 24.3% to 28.2%, while coal's share has declined. Nuclear and renewable energy sources have seen significant growth, now accounting for 11.7% and 8.2% of the energy mix, respectively. The demand for oil products in OECD countries continues to rely heavily on imports despite the gradual reduction in their share of global oil consumption. Given the documented structural variations in energy demand across OECD countries, nonlinear and time-varying estimation methodologies offer a more accurate framework for analyzing oil demand elasticities. These methodologies account for the dynamic factors influencing consumption patterns and provide deeper insights into the evolving role of oil within OECD energy systems. This approach is crucial for understanding future trends and informing energy policy and market strategies.
This study makes two key contributions to the existing literature on oil demand dynamics. First, it addresses the gap in research on time-varying estimations of oil demand income and price elasticities by employing a semiparametric local linear dummy variable (LLDV) estimator. This advanced and flexible estimation technique enables the analysis of time-varying parameters within a panel data framework, offering greater precision and robustness compared to traditional methods (Gorus & Groeneveld, 2018; Audi & Ali, 2018; Khan & Hassan, 2019; Desiree, 2019; Emodi, 2019; Mahmood, 2019; Al-Abri et al., 2019; Zaheer & Nasir, 2020; Bakht, 2020; Habibullah, 2020; Ali et al., 2021). By capturing the temporal dynamics of oil demand elasticities, this approach enhances our understanding of how sensitivity to income and price changes evolves over time. Second, the study utilizes a unique quarterly dataset, in contrast to the annual datasets typically used in prior research. This higher frequency data allows for more granular and reliable statistical inferences about oil demand elasticities, capturing short-term fluctuations and trends that annual data may overlook. The use of quarterly data enhances the precision of the findings and strengthens their applicability to policy and market contexts.
The insights gained from this analysis provide policymakers with valuable information on the responsiveness of oil consumption to income and price changes. Such knowledge is crucial for developing energy policies that not only address immediate economic needs but also align with long-term goals of sustainable economic growth and energy transition. By offering a deeper and more dynamic understanding of oil demand behavior, this study contributes to informed decision-making in energy policy and planning.

2. LITERATURE REVIEW

Kilian (2022) raises valid concerns about the reliability of certain methodologies used to estimate elasticities, questioning the validity of some results in the literature. Time-series analysis methods have been widely applied across various countries to estimate energy demand elasticities, offering valuable insights but also exposing methodological limitations. For example, Bentzen and Engsted (2001) conducted a study on energy demand in Denmark from 1960 to 1996. They found that the income elasticity of energy demand was 0.444, while the price elasticity was −0.354. The long-run elasticities were significantly higher, estimated at 1.294 for income and −1.032 for price, indicating a stronger response to changes in these variables over extended periods. Krichene (2002) analyzed global market data from 1918 to 1999 and found that the short-term price elasticity of crude oil demand was −0.06, with natural gas demand showing a similar value of −0.08, though not statistically significant. Short-term income elasticities were estimated at 0.53 for crude oil and 0.76 for natural gas. In the long term, price elasticities were estimated at −0.05 for crude oil and −0.7 for natural gas, while income elasticities stood at 0.6 and 1.75, respectively. These findings highlight the inelastic nature of oil demand, particularly with respect to price changes, and suggest a stronger long-term response to income variations.
In Mexico, Galindo (2005) found that price elasticities for energy demand were consistently around −0.2 in both the short and long terms. This consistency suggests that price changes have a relatively modest and stable effect on energy consumption in the Mexican context. These studies illustrate the diversity of elasticity estimates across countries and time periods. However, they also underscore the importance of methodological rigor and the need for caution in interpreting results, as elasticities can vary significantly based on the context, data frequency, and estimation techniques used. These variations further emphasize the importance of improving methodologies, such as incorporating time-varying frameworks, to enhance the reliability of elasticity estimates and their policy implications. The literature on energy demand elasticities provides diverse findings across different countries and energy types, reflecting variations in economic structure, energy consumption patterns, and market dynamics. De Vita et al. (2006) estimated the long-run income and price elasticities of energy demand in Namibia to be 1.27 and −0.34, respectively, indicating relatively strong responsiveness of energy demand to income changes and moderate sensitivity to price changes. Similarly, Altinay (2007) found the long-run income and price elasticities of oil demand in Turkey to be 0.61 and −0.18, respectively, showing weaker responsiveness compared to Namibia.
Akinboade et al. (2008) reported the price and income elasticities of gasoline demand in South Africa to be −0.47 and 0.36, respectively, highlighting a stronger price sensitivity in gasoline demand. Ghosh (2009) observed that India exhibited crude oil long-run income and price elasticities of 1.97 and −0.63, respectively, reflecting high-income responsiveness and significant sensitivity to price changes. Sa'ad (2009) estimated income and price elasticities of petroleum demand in Indonesia at 0.88 and −0.16, respectively, suggesting moderate responsiveness to income and price fluctuations. Using a time-varying co-integration method, Park and Zhao (2010) analyzed gasoline demand in the USA and found income and price elasticities

to be 0.073 and 0.247, respectively, indicating low income sensitivity but a positive price elasticity, an unusual finding likely influenced by specific market dynamics during the study period. Iwayemi et al. (2010) estimated long-term income and price elasticities of energy demand in Nigeria as 0.66 and −0.106, respectively, revealing limited sensitivity to both income and price changes. Ziramba (2010) reported crude oil demand elasticities in South Africa, with long-term price and income elasticities of −0.147 and 0.429, respectively, consistent with modest sensitivity. Moore (2011) found price and income elasticities of gasoline demand in Barbados to be −0.55 and 0.91, respectively, indicating a relatively strong response to price changes and a high degree of income sensitivity. These studies illustrate the variability in energy demand elasticities across countries, shaped by factors such as income levels, energy policies, market structures, and cultural consumption behaviors. The findings emphasize the importance of context-specific analysis and robust methodologies to accurately capture the dynamics of energy demand and inform effective policy-making.

Neto (2012) estimated the time-varying elasticities of gasoline demand in Switzerland, finding income and price elasticities of 0.692 and −0.167, respectively, suggesting moderate sensitivity to both factors. Further focusing on Switzerland, Baranzini and Weber (2013) analyzed fuel and gasoline demand for the period 1970–2008. Their findings showed long-run price elasticities of −0.34 and −0.27, respectively, while short-run price elasticities were significantly lower at −0.09 and −0.08. Long-run income elasticities were estimated at 0.67 and 0.76, respectively, whereas short-run income elasticities were found to be statistically insignificant, indicating a delayed response of demand to income changes in the short term. Kim and Baek (2013) estimated price and income elasticities for crude oil demand in Korea, reporting values of −0.43 and 1.31, respectively. These results suggest a high sensitivity to income changes, consistent with Korea's rapid economic development and industrial energy demands during the study period. Agrawal (2015) investigated crude oil, diesel, and petrol demand in India from 1970 to 2012. The price elasticities were estimated at −0.42, −0.71, and −0.85, respectively, while income elasticities were higher, at 0.97, 1.2, and 1.4, respectively. These findings reflect strong income-driven growth in energy consumption in India, coupled with relatively high price sensitivity, particularly for petrol.

Ozturk and Arisoy (2016) estimated crude oil import demand elasticities in Turkey, finding an income elasticity of 1.182 and a price elasticity of −0.026. The very low price elasticity highlights the inelastic nature of Turkey's crude oil import demand, likely due to limited domestic substitutes and the critical role of oil in its energy mix. These studies collectively underscore the diversity in energy demand elasticities across regions and energy types, influenced by factors such as economic growth, energy policies, and market structures. The results emphasize the importance of country-specific and energy-specific analyses to inform targeted and effective energy policies. Recent studies continue to provide diverse estimates of income and price elasticities for oil and fuel demand across different countries, illustrating variations based on economic structure, energy policies, and consumption patterns. Jebran et al. (2016), using an ARDL model for Pakistan, estimated the price elasticity of crude oil demand at −1.06, indicating significant sensitivity to price changes. The income elasticity was notably high at 3.35, reflecting strong income-driven growth in oil demand. In contrast, Dash et al. (2018) estimated India's oil import demand price elasticity at −0.43, showing moderate price responsiveness.

Marbuah (2018) analyzed Ghana's crude oil demand, reporting an income elasticity of 1.638 and a price elasticity of −1.277. These results suggest that both income and price changes significantly influence oil demand in Ghana. Shin et al. (2018) estimated Korea's crude oil demand elasticities, finding an income elasticity of 1.086 and a price elasticity of 0.177. The positive price elasticity in this case might reflect atypical demand dynamics or specific economic contexts. For Turkey, Gorus et al. (2019) estimated long-term crude oil import demand elasticities of −0.110 for price and 1.042 for income, highlighting the critical role of income in driving oil demand. Raghoo and Surroop (2020) estimated Mauritius' long-run fuel oil demand elasticities, with a price elasticity of −0.431 and an income elasticity of 1.19, reflecting substantial income-driven demand growth. Mikayilov et al. (2020) applied time-varying coefficient cointegration to Saudi Arabia, estimating that long-run income elasticities ranged between 0.6 and 1.1, while price elasticities varied between −0.5 and −0.1. These findings illustrate the evolving sensitivity of oil demand to economic and price changes over time. For Iran, Ghoddusi et al. (2022) estimated gasoline demand elasticities across different time horizons, with short-, intermediate-, and long-term price elasticities of −0.065, −0.207, and −0.291, respectively. Diesel demand showed lower responsiveness, with elasticities of −0.023, −0.059, and −0.116 over the same periods. These results underscore the inelastic nature of fuel demand in the short term, which becomes more price-sensitive over longer periods.

Javid et al. (2022) focused on Pakistan's natural gas demand and found income elasticities for all sectors ranging from 0.45 to 0.73, indicating moderate income sensitivity. These studies highlight significant variations in elasticity estimates across countries and energy types, reflecting unique socio-economic and market dynamics. They also underscore the importance of tailored energy policies that consider these differences to ensure effective resource management and sustainable energy transitions. Various scholars have applied time-series analysis methods to estimate energy demand elasticities across different groups of countries, revealing diverse responsiveness to price and income changes. Al-Faris (1992) focused on gasoline demand elasticities in OAPEC countries, finding short-term price elasticities ranging from −0.08 to −0.48 and long-term elasticities from −0.24 to −1.62. Income elasticities were estimated to range from 0.11 to 0.86 in the short run and from 0.92 to 0.86 in the long run, suggesting higher income responsiveness over longer periods. Dahl (1992) analyzed energy demand elasticities in 50 developing countries, reporting average price and income elasticities of −0.33 and 1.27, respectively. These findings underscore significant income-driven energy consumption growth in developing economies, paired with moderate price sensitivity.

Ghouri (2001) estimated price and income elasticities for gasoline demand in the USA, Canada, and Mexico. Price elasticities were −0.045, −0.06, and −0.13, respectively, while income elasticities were 0.98, 1.08, and 0.84, highlighting relatively low price sensitivity and strong income-driven demand. Cooper (2003) examined crude oil demand elasticities in 23 countries, reporting price elasticities ranging from 0.38 to −0.568. The variation suggests that oil demand elasticity is influenced by country-specific factors such as economic structure and market conditions. Asali (2011) estimated oil demand elasticities for BRICS and G7 countries, reporting average short- and long-run income elasticities of 0.41 and 0.78, respectively. Short- and long-run price elasticities averaged −0.05 and −0.15, respectively, indicating modest price sensitivity across these groups. Labandeira et al. (2017) conducted a meta-analysis of empirical studies on energy demand price elasticities, reviewing 428 articles estimating 966 short-run and 1010 long-run elasticities. They concluded that the average price elasticity of energy demand was approximately −0.21 in the short run and −0.61 in the long run, highlighting greater price responsiveness over extended periods. These studies illustrate the variability in energy demand elasticities across countries and contexts, driven by differences in income levels, energy policies, and market structures. The findings underscore the importance of tailoring energy policy to the specific economic and market conditions of each country or region to effectively address energy demand dynamics. The body of literature examining income and price elasticities of energy and oil demand reflects considerable variation across countries, energy types, and methodological approaches. Eleyan et al. (2021) analyzed oil demand in BRICS countries, reporting income elasticities ranging from 0.664 in India to 0.888 in Brazil. Price elasticities were significant for Brazil (−0.032), Russia (−0.265), and China (−0.089), indicating moderate price sensitivity in these countries. Focusing on gasoline demand, Lee and Olasehinde-Williams (2021) found predominantly negative price elasticities and positive income elasticities in China, India, the USA, Russia, and Japan. Pellini (2021) investigated residential electricity demand in 12 European countries, finding long-term income elasticities ranging from 0.93 to 0.00 and price elasticities from −0.80 to −0.08, highlighting significant regional variability.

Panel data methods have gained popularity for elasticity estimation, offering cross-country comparisons and improved generalizability. Gately and Huntington (2002) used a panel fixed-effects model to estimate income elasticities of energy and oil demand in OECD and non-OECD countries. Long-run income elasticities were 0.5 and 0.6, respectively, for energy and oil demand in OECD countries, compared to 1.0 and 0.5 in non-OECD countries. Narayan and Smyth (2007), employing panel cointegration tests, found income and price elasticities of oil demand at 1.014 and −0.015, respectively, indicating a stronger income effect and negligible price responsiveness. Dargay and Gately (2010) estimated OECD oil demand elasticities between 1971 and 2008, with income elasticity at 0.80 and price elasticity at −0.29. Using nonparametric methods, Karimu and Brännlund (2013) estimated energy demand price elasticity at −0.2. Yousef (2013) applied FMOLS and DOLS methods to OPEC countries, reporting income elasticities for gasoline, diesel, and kerosene demand as 0.53, 0.08, and 0.78, respectively, using FMOLS, and 0.57, 0.05, and 0.73, respectively, with DOLS. Javan and Zahran (2015), using dynamic panel methods, estimated short- and long-run income elasticities ranging from 0.15 to 1.09 and 0.21 to 1.54, respectively, and price elasticities between −0.05 and −0.20 in the short run and −0.11 and −0.36 in the long run.

Csereklyei (2020) examined EU electricity demand elasticities, finding residential electricity price elasticities between −0.53 and −0.56 and industrial electricity price elasticities ranging from −0.75 to −1.01. Income elasticities were 0.61 for residential electricity and ranged from 0.76 to 1.08 for industrial electricity. Sharma et al. (2021) analyzed six middle-income South Asian countries, reporting long-run income elasticities for crude oil demand between 0.47 and 0.54, while crude oil prices were found to have an insignificant impact on demand. Finally, Zheng et al. (2022) analyzed 49 countries from 1995 to 2017, reporting long-run income elasticities for oil demand ranging from 1.16 to 3.35. These findings illustrate substantial heterogeneity in income and price elasticities across regions and energy types, influenced by factors such as economic structure, energy policies, and market dynamics. The insights underscore the importance of context-specific approaches in energy policy formulation to address demand-side management effectively. To date, only a limited number of studies have explored the time-varying nature of price and income elasticities using panel data models, providing insights into the dynamic behavior of energy demand elasticities.

Liddle et al. (2020) examined the income and price elasticities of energy demand in 26 middle-income countries, emphasizing the dynamic evolution of these elasticities over time. They found an average income elasticity of 0.7, while the price elasticity coefficient was statistically insignificant, indicating limited sensitivity to price changes in these countries. Gao et al. (2021) applied a panel data approach to analyze 65 countries from 1960 to 2016, estimating income elasticities of energy demand ranging from 0.6 to 0.8 and price elasticities from −0.1 to −0.3. These findings reflect moderate income-driven growth in energy demand and low price sensitivity across a broad sample of countries. Liddle and Parker (2022) utilized a time-varying fixed-effects panel data model to study gasoline demand elasticities in 17 OECD countries from 1960 to 2017. Their findings highlighted the peak in the absolute value of price elasticity during the energy crises between 1973 and 1985, followed by a decline in the post-crisis years. Income elasticities, while not constant, displayed minimal deviations over time and remained relatively close to time-invariant estimates, suggesting stable income-driven gasoline demand in OECD countries. Liddle et al. (2022) focused on the income and price elasticities of road fuel demand in 26 countries between 1990 and 2019. They estimated that income elasticities ranged from 1 to 0.8, indicating a gradual decline in income responsiveness over time. Price elasticities were approximately −0.2, showing modest price sensitivity across the sample. These studies underscore the importance of accounting for time-varying dynamics in energy demand analyses. By capturing the evolution of elasticities over time, such approaches provide a more nuanced understanding of energy consumption behavior, offering valuable insights for policymakers in designing adaptive and forward-looking energy policies.

3. THE MODEL

To analyze the impact of oil prices and economic activity on oil demand, consistent with the literature, we specify a double-log model. This formulation allows us to interpret the coefficients directly as elasticities, providing clear insights into the responsiveness of oil demand to changes in these variables. Our study diverges from previous research by utilizing quarterly data instead of annual data, enhancing the granularity and reliability of our estimates. The dataset includes observations from 21 OECD countries, spanning the first quarter of 1980 to the third quarter of 2023. Based on this approach, our nonparametric model is expressed as follows:

$$lQ_{it} = f(t) + \beta_1 Y_{it} + \beta_2 P_{it} + f_i(t) + \varepsilon_{it}$$

where Δ stands for the first-difference operator; f_i *(t)* represents unknown individual trend functions; β_j *(t)* for *j = 1,…,N* shows the time-varying coefficients. The error term, ε_{it}, is assumed to be stationary for each cross-section.

4. RESULTS AND DISCUSSIONS

Table 1 provides descriptive statistics for the elasticities studied, specifically price elasticity and income elasticity, along with the number of observations, mean values, ranges (maximum and minimum), and standard deviations. The data also includes the time periods covered, with specific quarters indicating the first and last observations. Price elasticity, which measures the responsiveness of demand to changes in price, has 166 observations. The mean value is −0.098, indicating that, on average, demand decreases slightly when prices increase. The maximum value is 0.275, suggesting a few instances where demand positively correlates with price changes, which may occur in unusual market conditions. The minimum value is −0.396, indicating scenarios with a stronger negative price response. The standard deviation of 0.134 shows moderate variability in price elasticity across observations. The time period spans from the second quarter of 1991 to the first quarter of 2020.

Income elasticity, which measures the responsiveness of demand to changes in income, also has 166 observations. The mean value is 0.189, indicating that demand generally increases with rising income. The maximum value of 0.855 reflects instances of a strong positive income effect, while the minimum value of 0.01 shows cases where income changes have little impact on demand. The standard deviation is 0.159, suggesting slightly higher variability compared to price elasticity. The time period extends from the fourth quarter of 1985 to the first quarter of 2020. These statistics illustrate that price elasticity is typically negative, as expected in most economic contexts, while income elasticity is positive, reflecting normal consumption behavior. The variability in both elasticities highlights differences in market dynamics, consumer behavior, and external factors influencing demand over the observed period.

Table 1: Descriptive Statistics

Elasticities	Mean	Maximum	Minimum	SD
Price elasticity	−0.098	0.275	−0.396	0.134
Income elasticity	0.189	0.855	0.01	0.159

To determine the integration order of the variables, we employ the Cross-Sectionally Augmented IPS (CIPS) panel unit root test developed by Pesaran (2007). This test accounts for cross-sectional dependence across countries, providing robust results in a panel data setting. The findings, presented in Table 2, indicate that all variables exhibit first-order integration, denoted as I(1)I(1)I(1). This suggests that the variables are non-stationary in levels but become stationary after first differencing. These results confirm that the data are suitable for further analysis using cointegration techniques, which are appropriate for examining the long-run relationships among variables that share the same integration order. The confirmation of I(1)I(1)I(1) integration ensures the validity of employing advanced econometric methods, such as the ARDL approach or panel cointegration tests, to explore the dynamics of oil demand, oil prices, and economic activity.

Table 2: Pesaran (2007) CIPS panel unit root test results

Variables	lq_{it}	Ly_{it}	Lp_{it}
Level	−2.253	−2.231	−2.209
First difference	−6.138***	−6.14***	−6.19***

*, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively

Table 2 presents the results of the Pesaran (2007) CIPS panel unit root test. The test evaluates the stationarity of these variables at both levels and first differences. Statistical significance is denoted by one, two, and three asterisks, representing the 10%, 5%, and 1% significance levels, respectively. At the level, all three variables—lq_{it}, ly_{it}, and lp_{it}—have test statistics of −2.253, −2.231, and −2.209, respectively. None of these values reach the threshold for statistical significance at conventional levels, suggesting that the variables are non-stationary in their original forms. After differencing, the test statistics for all three variables become highly significant at the 1% level. For lq_{it}, ly_{it}, and lp_{it}, the first difference test statistics are −6.138, −6.14, and −6.19, respectively. These results indicate that the variables become stationary after first differencing, suggesting they are integrated of order one (I(1)). In summary, the CIPS panel unit root test results demonstrate that lq_{it}, ly_{it}, and lp_{it} are non-

stationary at levels but achieve stationarity after first differencing. This finding is critical for further econometric modeling, as it ensures the variables meet the stationarity requirement for techniques like cointegration analysis and error correction models.
Table 3 presents the results of the Westerlund (2007) cointegration test, which assesses the presence of long-run relationships among variables in a panel data set. The test statistics include GtGtGt, GaGaGa, PtPtPt, and PaPaPa, along with their respective values, Z-statistics, p-values, and robust p-values. The GtGtGt statistic has a value of −4.430 and a Z-statistic of −10.361. Both the standard p-value and the robust p-value are 0.0000, indicating strong evidence against the null hypothesis of no cointegration. This suggests that a significant portion of the panel exhibits cointegration. The GaGaGa statistic, which evaluates group-mean cointegration, has a value of −27.866 and a Z-statistic of −8.898. Like the GtGtGt statistic, both p-values are 0.0000, reinforcing the conclusion of cointegration across groups. The PtPtPt statistic, representing the panel cointegration test based on pooled information, has a value of −19.698 and a Z-statistic of −10.215. Again, the p-values confirm significant cointegration across the panel.
Lastly, the PaPaPa statistic, which assesses pooled panel cointegration with an adjusted approach, has a value of −26.758 and a Z-statistic of −11.031. Both p-values remain at 0.0000, providing further robust evidence of cointegration. In sum, all four test statistics—GtGtGt, GaGaGa, PtPtPt, and PaPaPa—yield highly significant results, indicating a strong rejection of the null hypothesis of no cointegration. This implies the existence of stable long-run relationships among the variables in the panel data, which is essential for reliable econometric modeling and policy analysis.

Table 3: Westerlund (2007) cointegration test results

Statistic	Value	Z	P value
Gt	−4.430	−10.361	0.0000
Ga	−27.866	−8.898	0.0000
Pt	−19.698	−10.215	0.0000
Pa	−26.758	−11.031	0.0000

Table 4 presents the results of the Westerlund and Edgerton (2008) panel cointegration test, which accounts for structural breaks in the data. The test evaluates three models—no shift, level shift, and regime shift—using the Zτ(N)Zτ (N)Zτ(N) and Zϕ(N)Zϕ (N)Zϕ(N) test statistics. The corresponding p-values indicate the significance of the results. In the no shift model, which assumes no structural break, the Zτ(N)Zτ (N)Zτ(N) test statistic is −9.832, and the Zϕ(N)Zϕ (N)Zϕ(N) statistic is −11.942. Both test statistics have p-values of 0.000, indicating strong rejection of the null hypothesis of no cointegration. This suggests evidence of cointegration in the absence of structural breaks. For the level shift model, which allows for a one-time structural shift in the level of the series, the Zτ(N)Zτ (N)Zτ(N) statistic is −3.786, and the Zϕ(N)Zϕ (N)Zϕ(N) statistic is −3.767. Both are highly significant, with p-values of 0.000. This indicates that even when accounting for a structural shift in the level, there is strong evidence of cointegration.
In the regime shift model, which accommodates changes in both the level and trend of the series, the Zτ(N)Zτ (N)Zτ(N) test statistic is −2.774, with a p-value of 0.003, and the Zϕ(N)Zϕ (N)Zϕ(N) statistic is −2.981, with a p-value of 0.001. These results are also significant, though at slightly higher p-value thresholds compared to the other models, suggesting that cointegration persists even under more complex structural changes. All three models—no shift, level shift, and regime shift—provide significant evidence of cointegration across the panel, even when accounting for structural breaks. This indicates the presence of robust long-run relationships among the variables, regardless of shifts or changes in the data structure over time. These findings reinforce the stability of the cointegration relationships in the context of structural breaks, making them suitable for further econometric analysis and modeling.

Table 4: Westerlund and Edgerton (2008) panel cointegration with structural break test results

	Test statistics	P	Test statistics	P
No shift	−9.832	0.000	−11.942	0.000
Level shift	−3.786	0.000	−3.767	0.000
Regime shift	−2.774	0.003	−2.981	0.001

Table 5 presents the long-run parameter estimates for a group of 21 countries, examining the effects of two explanatory variables on a dependent variable using the Augmented Mean Group estimator. The results show that most countries have a positive and statistically significant long-run relationship for the first explanatory variable. Countries such as Australia, Canada, and the Netherlands demonstrate strong positive effects, suggesting that this variable positively influences the dependent variable over time. However, there are notable exceptions where countries such as Denmark, France, and Germany exhibit negative relationships, indicating a long-run negative impact of this variable. The second explanatory variable predominantly shows a negative and significant long-run relationship across most countries. This is evident in countries like Italy, Portugal, and Japan, where the variable has a substantial negative effect on the dependent variable. Despite this general trend, some countries, such as Austria and Spain, show positive and significant relationships, highlighting that the impact of this variable may vary depending on the specific context of the country. When looking at the overall panel results, the first explanatory variable exhibits a positive long-run effect, while the second variable shows a negative impact. This suggests that, on average, the first variable contributes positively to the dependent variable, whereas the second variable tends to exert a negative influence across the panel. These findings underscore the importance of considering both individual country dynamics and overarching trends, as the relationships between variables can vary significantly across different economic and social contexts.

Table 5: Long-run parameter estimates based on the AMGEstimator

Countries list	AMG	
	Ly_{it}	lp_{it}
1. Australia	0.3910***	−0.2564***
2. Austria	0.1378***	0.2185***
3. Belgium	0.2316***	0.0438*
4. Canada	0.3732***	−0.0933***
5. Denmark	−0.1330**	−0.3498***
6. Finland	0.0402***	−0.1619***
7. France	−0.0693***	−0.0588**
8. Germany	−0.0593***	−0.2036***
9. Greece	0.0779***	−0.1786***
10. Ireland	0.3389***	−0.1801**
11. Italy	−0.1070***	−0.6352***
12. Japan	−0.1042***	−0.3345***
13. Netherlands	0.5184***	−0.4267***
14. Norway	0.1052***	−0.0779*
15. Portugal	0.1313***	−0.6388***
16. Spain	0.1726***	0.1062***
17. Sweden	−0.1552***	−0.1362**
18. Switzerland	−0.0438***	−0.1614***
19. Turkey	0.4615***	0.0047
20. United Kingdom	0.0180**	−0.2511***
21. United States	0.1409***	0.0065
Panel	0.1174***	−0.1792***

*, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively

Elasticities lower than one confirm that oil can generally be considered a necessary good, as the quantity demanded does not strongly respond to price changes. Our estimated price elasticities provide nuanced insights into oil demand dynamics over time. Until 2014, the elasticities are negative, consistent with the law of demand, indicating that higher oil prices led to reduced oil consumption. For instance, during the 1990s, the elasticity was approximately −0.3, implying that a ten-percent increase in oil prices resulted in a 3% reduction in oil demand. This relatively inelastic response suggests that consumers had limited flexibility in adjusting their oil consumption despite price increases. However, a notable shift occurs post-2014, with estimated elasticities becoming positive. This counterintuitive finding implies that higher oil prices were associated with increased oil demand, contradicting the traditional law of demand. For example, during the 2010s, the elasticity was around 0.2, indicating that a ten-percent increase in oil prices corresponded to a 2% rise in oil demand. This change could reflect structural shifts in the oil market, such as declining oil prices encouraging speculative buying, investments in oil-related sectors, or shifts in demand patterns driven by economic or geopolitical factors.

The time-varying nature of these elasticities is evident, with statistically significant estimates for most periods, except for occasional quarters when the two standard error bands include zero. These variations underscore the dynamic interplay of economic, technological, and market-specific factors influencing oil demand. The findings highlight the importance of accounting for temporal and structural changes when analyzing energy demand and formulating policies. The observed changes in estimated oil price elasticities over time appear closely tied to the interplay between global economic events and fluctuations in oil prices. During the 1980s and early 1990s, when oil prices were generally low and global economic growth was weak, the estimated elasticities were predominantly negative, consistent with the law of demand. For instance, the largest negative elasticity was recorded in the second quarter of 1991, coinciding with the First Gulf War, during which increasing oil prices and declining oil production significantly curtailed oil demand. As the global economy strengthened in the 2000s and 2010s, accompanied by sustained high oil prices, the negative elasticities became less pronounced. This suggests that rising incomes and robust economic activity may have partially offset the price sensitivity of oil demand during this period. However, a distinct shift occurred post-2015, with estimated elasticities turning positive. This anomaly could reflect structural changes in oil demand or market dynamics, including the adoption of new technologies, the proliferation of alternative energy sources, or geopolitical factors that influenced oil prices and consumption patterns (Afolabi & Yusuf, 2019). The positive price elasticities observed after 2015, particularly during the oil price decline from $106 per barrel in 2014 to $37 in 2015, challenge the traditional law of demand. However, these elasticities were often statistically insignificant, as the two standard error confidence bands included zero. A notable exception was in 2020, when the largest positive and statistically significant price elasticity, 0.28, was recorded. This unique finding can be attributed to the unprecedented impact of the COVID-19 pandemic, which dramatically reduced economic activity and oil demand as countries implemented lockdowns. The resulting sharp decline in crude oil prices, falling to $29 per barrel and even turning negative in forward spot markets, created atypical market conditions that temporarily altered demand dynamics.These findings underscore the critical role of global economic and geopolitical events in shaping the responsiveness of oil demand to price changes over time. They also highlight the need for policymakers and market participants to consider the evolving nature of oil demand elasticities when designing energy policies and market strategies.

The estimated income elasticity of 0.117 indicates that a one-percent increase in real income leads to a 0.117% rise in oil demand. This relatively low elasticity suggests that oil demand in OECD countries is not highly sensitive to income changes, likely reflecting the saturation of energy demand in developed economies. The estimated oil price elasticity of −0.179 signifies that a one-percent increase in real oil prices reduces oil demand by 0.179%, confirming that oil demand is price inelastic in these countries. These findings align with prior research on OECD nations, such as Gately and Huntington (2002), Dargay and Gately (2010), Karimu and Brännlund (2013), and Javan and Zahran (2015), which similarly reported modest responsiveness of oil demand to price and income changes. To ensure the robustness of our results, we tested the stability of the long-run relationship among the variables using a panel cointegration test that accounts for endogenous structural breaks. The test results rejected the null hypothesis of no cointegration, indicating the presence of a long-term equilibrium relationship in the oil demand equation despite potential structural shifts. This finding is consistent with the results reported in studies such as Narayan and Smyth (2007), Karimu and Brännlund (2013), Yousef (2013), and Sharma et al. (2021), which have also identified stable long-term relationships in similar contexts. The identification of structural breaks further underscores the dynamic nature of oil demand, as economic events, technological advancements, and policy changes can influence consumption patterns over time. These results highlight the importance of incorporating flexibility in modeling frameworks to account for such structural shifts, providing more accurate and context-sensitive insights into the determinants of oil demand.

5. CONCLUSIONS

This study analyzed the income and oil price elasticities of oil demand in OECD countries using advanced econometric approaches, including second-generation panel time-series analysis and a time-varying panel data model based on the local linear dummy variable estimator. These methods allowed for a robust examination of the dynamic relationships among the variables while accounting for cross-sectional dependence and heterogeneity across countries. The findings underscore the responsiveness of oil consumption to fluctuations in income and oil prices, confirming that oil demand in OECD countries is generally inelastic but varies over time and across nations. The estimated elasticities reveal that income plays a modest role in driving oil demand, while price sensitivity remains low, consistent with previous research. However, temporal and regional differences highlight the influence of economic conditions, policy interventions, and market dynamics on-demand elasticity.

By capturing variations in elasticities over time and between countries, this study provides nuanced insights into the determinants of oil demand. These results emphasize the importance of tailoring energy policies to specific economic and regional contexts, ensuring effective management of energy consumption in line with sustainability goals. The results of this study indicate a significant long-run relationship between oil demand, real income, and real oil prices. Both estimated long-run income and oil price elasticities are less than unity, confirming that oil demand in OECD countries is inelastic concerning both income and price. This suggests that changes in income or oil prices lead to proportionally smaller changes in oil consumption, reflecting the essential nature of oil in these economies and its limited substitutability in the short term. To ensure the robustness of the long-run relationship, we employed a panel cointegration test that incorporates endogenous structural breaks. The test results rejected the null hypothesis of no cointegration, providing evidence for the existence of a stable long-term equilibrium relationship among the variables. The incorporation of endogenous breaks also indicates that the long-run relationship may have been influenced by structural shifts at unknown points in time, such as economic crises, technological advancements, or significant policy changes. These findings reinforce the importance of understanding the long-term dynamics of oil demand, particularly in the context of economic growth and price fluctuations. The results also highlight the need for adaptive energy policies that account for potential structural changes, ensuring stability and sustainability in energy consumption patterns over time. Our analysis of time-varying panel data estimates reveals significant temporal variations in both income and oil price elasticities, shedding light on the evolving responsiveness of oil consumption to economic and market changes. The estimated elasticities highlight the inelastic nature of oil demand in OECD countries, indicating that changes in income or oil prices result in proportionally smaller changes in oil consumption. This inelasticity reflects oil's essential role in these economies, where substitution options remain limited in the short to medium term. The findings provide valuable insights for policymakers, enabling them to anticipate the impacts of economic growth and oil price fluctuations on oil demand. The observed variation in elasticities over time underscores the importance of designing flexible and adaptive energy policies that can accommodate changing market conditions, technological advancements, and global events. For instance, during periods of economic expansion or price volatility, responsive policies can help stabilize energy markets and ensure sustainable consumption patterns. By emphasizing the dynamic nature of elasticities, this study contributes to a more nuanced understanding of oil demand behavior. These insights are critical for accurately forecasting future oil demand and developing strategies to manage energy resources effectively while transitioning toward cleaner and more sustainable energy systems.

REFERENCES

Afolabi, R.O., & Yusuf, E.O. (2019). Nanotechnology and global energy demand: Challenges and prospects for a paradigm shift in the oil and gas industry. *Journal of Petroleum Exploration and Production Technology, 9*, 1423-1441.

Agrawal, P. (2015). India's petroleum demand: Estimations and projections. *Applied Economics, 47*, 1199-1212.

Akinboade, O.A., Ziramba, E., & Kumo, W.L. (2008). The demand for gasoline in South Africa: An empirical analysis using cointegration techniques. *Energy Economics*, *30*, 3222-32229.

Al-Faris, A.F. (1992). Income and price elasticities of gasoline demand in the organization of Arab petroleum exporting countries. *The Journal of Energy and Development*, *17*(2), 209-223.

Ali, A., & Audi, M. (2016). The Impact of Income Inequality, Environmental Degradation and Globalization on Life Expectancy in Pakistan: An Empirical Analysis. *International Journal of Economics and Empirical Research (IJEER)*, *4*(4), 182-193.

Ali, A., Audi, M., & Roussel, Y. (2021). Natural resources depletion, renewable energy consumption and environmental degradation: A comparative analysis of developed and developing world. *International Journal of Energy Economics and Policy*, *11*(3), 251-260.

Ali, A., Audi, M., Bibi, C., & Roussel, Y. (2021). The Impact of Gender Inequality and Environmental Degradation on Human Well-being in the Case of Pakistan: A Time Series Analysis. *International Journal of Economics and Financial Issues*, *11*(2), 92-99.

Ali, A., Audi, M., Senturk, I., & Roussel, Y. (2022). Do sectoral growth promote CO2 emissions in Pakistan?: time series analysis in presence of structural break. *International Journal of Energy Economics and Policy*, *12*(2), 410-425.

Ali, A., Sumaira, S., Siddique, H. M. A., & Ashiq, S. (2023). *Impact of Economic Growth, Energy Consumption and Urbanization on Carbon Dioxide Emissions in the Kingdom of Saudi Arabia*. University Library of Munich, Germany.

Altinay, G. (2007). Short-run and long-run elasticities of import demand for crude oil in Turkey. *Energy Policy, 35*, 5829-5835.

Asali, M. (2011). Income and price elasticities and oil-saving technological changes in ARDL models of demand for oil in G7 and BRIC. *OPEC Energy Review, 35*(3), 189-219.

Audi, M., & Ali, A. (2017). *Environmental Degradation, Energy consumption, Population Density and Economic Development in Lebanon: A time series Analysis (1971-2014)*. University Library of Munich, Germany.

Audi, M., & Ali, A. (2018). *Determinants of Environmental Degradation under the Perspective of Globalization: A Panel Analysis of Selected MENA Nations*. University Library of Munich, Germany.

Audi, M., & Ali, A. (2023). Unveiling the Role of Business Freedom to Determine Environmental Degradation in Developing Countries. *International Journal of Energy Economics and Policy*, *13*(5), 157-164.

Audi, M., Poulin, M., & Ali, A. (2024). Environmental impact of business freedom and renewable energy: a global perspective. *International Journal of Energy Economics and Policy*, *14*(3), 672-683.

Bakht, Z. (2020). The Nexus between Economic Growth, Energy Consumption, and Environmental Pollution in Bangladesh. *Journal of Energy and Environmental Policy Options*, *3*(1), 1-8.

Baranzini, A., & Weber, S. (2013). Elasticities of gasoline demand in Switzerland. *Energy Policy, 63*, 674-680.

Bentzen, J., & Engsted, T. (2001). A revival of the autoregressive distributed lag model in estimating energy demand relationships. *Energy*, *26*, 45-55.

Chang, B., Kang, S. J., & Jung, T. Y. (2019). Price and output elasticities of energy demand for industrial sectors in OECD countries. *Sustainability*, *11*(6), 1786.

Cooper, J.C.B. (2003). Price elasticity of demand for crude oil: Estimates for 23 countries. *OPEC Review, 27*(1), 1-8.

Csereklyei, Z. (2020). Price and income elasticities of residential and industrial electricity demand in the European Union. *Energy Policy*, *137*, 111079.

Dahl, C. (1992). A survey of energy demand elasticities for the developing world. *The Journal of Energy and Development, 18*(1), 1-47.

Dargay, J.M., & Gately, D. (2010). World oil demand's shift toward faster growing and less price-responsive products and regions. *Energy Policy, 38*(10), 6261-6277.

Dash, D.P., Sethi, N., & Bal, D.P. (2018). Is the demand for crude oil inelastic for India? Evidence from structural VAR analysis. *Energy Policy, 118*, 552-558.

De Vita, G., Endresen, K., & Hunt, L.C. (2006). An empirical analysis of energy demand in Namibia. *Energy Policy, 34*, 3447-3463.

Desiree, B. (2019). Dynamic Analysis of Energy Consumption and Environmental Impact on GDP in Sub-Saharan Africa. *Journal of Energy and Environmental Policy Options*, *2*(1), 18-26.

Eleyan, M.I.A., Çatık, A.N., Balcılar, M., & Ballı, E. (2021). Are long-run income and price elasticities of oil demand time-varying? New evidence from BRICS countries. *Energy, 229*, 120710.

Emodi, S. A. (2019). Analyzing the Nexus between Energy Consumption, CO2 Emissions, and Economic Growth in Nigeria. *Journal of Energy and Environmental Policy Options*, *2*(3), 84-94.

Galindo, L.M. (2005). Short-and long-run demand for energy in Mexico: A cointegration approach. *Energy Policy, 33*, 1179-1185.

Gao, J., Peng, B., & Smyth, R. (2021). On income and price elasticities for energy demand: A panel data study. *Energy Economics, 96*, 105168.

Gately, D., & Huntington, H.G. (2002). The asymmetric effects of changes in price and income on energy and oil demand. *Energy Journal, 23*(1), 19-55.

Ghoddusi, H., Morovati, M., & Rafizadeh, N. (2022). Dynamics of fuel demand elasticity: Evidence from Iranian subsidy reforms. *Energy Economics, 110*, 106009.

Ghosh, S. (2009). Import demand of crude oil and economic growth: Evidence from India. *Energy Policy, 37*, 699-702.

Ghouri, S.S. (2001). Oil demand in North America: 1980-2020. *OPEC Review, 25*(4), 339-355.

Gorus, M.S., Ozgur, O., & Develi, A. (2019). The relationship between oil prices, oil imports and income level in Turkey: Evidence from Fourier approximation. *OPEC Energy Review, 43*(3), 327-341.

Gorus, S., & Groeneveld, R. (2018). Vietnam's Development Trajectory: Threshold Cointegration and Causality Analysis of Energy Consumption and Economic Growth. *Journal of Energy and Environmental Policy Options*, *1*(2), 28-35.

Habibullah, M. (2020). Understanding Energy Consumption Dynamics in Malaysia: An Empirical Analysis. *Journal of Energy and Environmental Policy Options*, *3*(1), 9-19.

Hussain, M., & Khan, A. R. (2022). The Impact of Economic Growth, Energy Consumption, and Trade Openness on Carbon Emissions in Pakistan. *Journal of Energy and Environmental Policy Options*, *5*(3), 1-6.

Iqbal, Z., & Noor, M. (2023). The Impact of Energy Consumption on Economic Growth in Selected Emerging Economies. *Journal of Energy and Environmental Policy Options*, *6*(2), 29-35.

Iwayemi, A., Adenikinju, A., & Babatunde, M.A. (2010). Estimating petroleum products demand elasticities in Nigeria: A multivariate cointegration approach. *Energy Economics, 32*, 73-85.

Javan, A., & Zahran, N. (2015). Dynamic panel data approaches for estimating oil demand elasticity. *OPEC Energy Review, 39*(1), 53-76.

Javid, M., Khan, F.N., & Arif, U. (2022). Income and price elasticities of natural gas demand in Pakistan: A disaggregated analysis. *Energy Economics, 113*, 106203.

Jebran, K., Abdullah, D., Elhabbaq, M.M., & Ali, A. (2017). Income and price elasticities of crude oil demand in Pakistan. *Global Business Review, 18*(6), 1373-1383.

Karimu, A., & Brännlund, R. (2013). Functional form and aggregate energy demand elasticities: A nonparametric panel approach for 17 OECD countries. *Energy Economics, 36*, 19-27.

Khan, M. N., & Hassan, T. (2019). Balancing Economic Growth and Environmental Sustainability through Energy Consumption in Pakistan. *Journal of Energy and Environmental Policy Options*, *2*(4), 109-116.

Kibritcioglu, A. (2023). Financial Development and Energy Consumption Dynamics in Turkey. *Journal of Energy and Environmental Policy Options*, *6*(2), 1-8.

Kilian, L. (2022). Understanding the estimation of oil demand and oil supply elasticities. *Energy Economics, 107*, 105844.

Kim, H.S., & Baek, J. (2013). Assessing dynamics of crude oil import demand in Korea. *Economic Modelling, 35*, 260-263.

Krichene, N. (2002). World crude oil and natural gas: A demand and supply model. *Energy Economics, 24*, 557-576.

Labandeira, X., Labeaga, J.M., & López-Otero, X. (2017). A meta-analysis on the price elasticity of energy demand. *Energy Policy, 102*, 549-568.

Lee, C., & Olasehinde-Williams, G. (2021). Gasoline demand elasticities in the world's energy gluttons: A time-varying coefficient approach. *Environmental Science and Pollution Research, 28*, 64830-64847.

Liddle, B. (2022). What is the temporal path of the GDP elasticity of energy consumption in OECD countries? An assessment of previous findings and new evidence. *Energies, 15*(10), 3802.

Liddle, B. (2023). Is timing everything? Assessing the evidence on whether energy/electricity demand elasticities are time-varying. *Energy Economics*, 106872.

Liddle, B., & Parker, S. (2022). One more for the road: Reconsidering whether OECD gasoline income and price elasticities have changed over time. *Energy Economics, 114*, 106280.

Liddle, B., Hasanov, F.J., & Parker, S. (2022). Your mileage may vary: Have road-fuel demand elasticities changed over time in middle-income countries? *Transportation Research Part A: Policy and Practice, 165*, 38-53.

Liddle, B., Smyth, R., & Zhang, X. (2020). Time-varying income and price elasticities for energy demand: Evidence from a middle-income panel. *Energy Economics, 86*, 104681.

Mahmood, H. (2019). Exploring the Dynamics Nexus of Energy Consumption, Economic Growth, Capital Stock, and Labor Force. *Journal of Energy and Environmental Policy Options*, *2*(3), 78-83.

Marbuah, G. (2018). Understanding crude oil import demand behaviour in Ghana. *Journal of African Trade, 4*, 75-87.

Mikayilov, J.I., Joutz, F.L., & Hasanov, F.J. (2020). Gasoline demand in Saudi Arabia: Are the price and income elasticities constant? *Energy Sources, Part B: Economics, Planning, and Policy, 15*(4), 211-229.

Moore, A. (2011). Demand elasticity of oil in Barbados. *Energy Policy, 39*, 3515-3519.

Mubiinzi, G., Senyonga, L., Kaawaase, T. K., Wasswa, F., Adaramola, M. S., & Nantongo, M. (2024). Income and price elasticities of household electricity demand: A comparative systematic review of aggregated and disaggregated data studies. *Energy Reports, 12,* 4449-4465.

Narayan, P.K., & Smyth, R. (2007). A panel cointegration analysis of the demand for oil in the Middle East. *Energy Policy, 35*, 6258-6265.

Neto, D. (2012). Testing and estimating time-varying elasticities of Swiss gasoline demand. *Energy Economics, 34*, 1755-1762.

Ozturk, I., & Arisoy, I. (2016). An estimation of crude oil import demand in Turkey: Evidence from time-varying parameters approach. *Energy Policy, 99*, 174-179.

Park, S.Y., & Zhao, G. (2010). An estimation of US gasoline demand: A smooth time-varying cointegration approach. *Energy Economics, 32*, 110-120.

Patiño, L. I., Padilla, E., Alcántara, V., & Raymond, J. L. (2020). The relationship of energy and CO2 emissions with GDP per capita in Colombia. *Atmosphere, 11*(8), 778.

Pellini, E. (2021). Estimating income and price elasticities of residential electricity demand with autometrics. *Energy Economics*, *101*, 105411.

Pesaran, M.H. (2004). General Diagnostic Tests for Cross-sectional Dependence in Panels. *Cambridge Working Papers in Economics 0435,* Faculty of Economics, University of Cambridge.

Pesaran, M.H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics, 22*, 265-312.

Raghoo, P., & Surroop, D. (2020). Price and income elasticities of oil demand in Mauritius: An empirical analysis using cointegration method. *Energy Policy, 140*, 111400.

Rossi, S. (2023). Exploring the Relationship between Economic Growth, Energy Consumption, Trade Openness, and Carbon Dioxide Emissions: A Case Study of Italy. *Journal of Energy and Environmental Policy Options*, *6*(3), 19-24.

Sa'ad, S. (2009). An empirical analysis of petroleum demand for Indonesia: An application of the cointegration approach. *Energy Policy, 37*, 4391-4396.

Senturk, I. (2023). The Impact of Financial Development and Energy Prices on Turkey's Energy Consumption. *Journal of Energy and Environmental Policy Options*, *6*(1), 24-29.

Shahbaz, M., Ozturk, I., & Ali, A. (2016). Does financial development lower environmental quality in Saudi Arabia? Fresh evidence from linear and non-linear specifications. *International Journal of Economics and Empirical Research (IJEER)*, *4*(7), 376-392.

Sharma, R., Kautish, P., & Kumar, D.S. (2021). Assessing dynamism of crude oil demand in middle-income countries of South Asia: A panel data investigation. *Global Business Review, 22*(1), 169-183.

Shin, C., Baek, J., & Heo, E. (2018). Do oil price changes have symmetric or asymmetric effects on Korea's demand for imported crude oil? *Energy Sources, Part B: Economics, Planning, and Policy, 13*(1), 6-12.

Uche, E., Ihezukwu, V. A., Osunkwo, F. O. C., & Okoronkwo, C. (2021). Does oil consumption respond asymmetrically to oil price, exchange rate and income differentials. *J. Ekon. Malays, 55*, 51-63.

Westerlund, J. (2007). Testing for error correction in panel data. *Oxford Bulletin of Economics and Statistics, 69*, 708-748.

Westerlund, J., & Edgerton, D.L. (2008). A simple test for cointegration in dependent panels with structural breaks. *Oxford Bulletin of Economics and Statistics, 70*(5), 665-704.

Yetkiner, H., & Berk, I. (2023). Energy intensity and directed fiscal policy. *Economic Systems, 47*(2), 101070.

Yılmaz, H., & Şahin, M. (2023). Solar panel energy production forecasting by machine learning methods and contribution of lifespan to sustainability. *International Journal of Environmental Science and Technology*, *20*(10), 10999-11018.

Yousef, A.N. (2013). Demand for oil products in OPEC countries: A panel cointegration analysis. *International Journal of Energy Economics and Policy, 3*(2), 168-177.

Zaheer, A., & Nasir, W. (2020). Exploring the Relationship Between Economic Freedom and Energy Consumption in Pakistan. *Journal of Energy and Environmental Policy Options*, *3*(2), 56-64.

Zheng, X., Wang, R., Liddle, B., Wen, Y., Lin, L., & Wang, L. (2022). Crude oil footprint in the rapidly changing world and implications from their income and price elasticities. *Energy Policy, 169*, 113204.

Ziramba, E. (2010). Price and income elasticities of crude oil import demand in South Africa: A cointegration analysis. *Energy Policy, 38*, 7844-7849.