International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2025, 15(2), 715-727.

Impact of Crude Oil Price Volatility on Procurement and Inventory Strategies in the Middle East

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Received: 30 November 2024 **Accepted:** 15 February 2025 **DOI:** https://doi.org/10.32479/ijeep.18950

ABSTRACT

Crude oil price volatility is a critical factor influencing procurement costs and inventory management in oil-dependent industries. This study examines the impact of crude oil price fluctuations on procurement expenses and inventory turnover, providing empirical insights into how businesses respond to oil market uncertainties. Given the direct link between oil price changes and supply chain costs, understanding these relationships is essential for developing risk mitigation strategies and enhancing supply chain resilience. The study employs time series analysis (ARIMA), econometric modelling (multivariate regression), and sensitivity analysis to quantify the effects of crude oil price volatility on procurement and inventory decisions. Data from multiple firms across industries were analysed to assess how fluctuations in oil prices influence procurement expenses, inventory turnover, and firm-level procurement strategies. Results indicate that higher crude oil price volatility leads to a significant increase in procurement costs, with an estimated impact of $3.96 million per unit increase in volatility. Additionally, inventory turnover declines as oil price volatility rises, as firms tend to hold onto stock longer to hedge against price uncertainty. Larger firms experience higher procurement costs but benefit from economies of scale, while smaller firms rely on agility and flexible sourcing strategies to manage cost fluctuations. The findings emphasize the need for predictive analytics, supplier diversification, and adaptive inventory management to mitigate procurement risks. Businesses must adopt data-driven procurement strategies and AI-driven forecasting models to navigate crude oil price uncertainties effectively. Future research should explore industry-specific procurement trends and the role of sustainability in reducing oil price dependencies.

Keywords: Crude Oil Price Volatility, Procurement, Inventory Management, Supply Chain Risk, Middle East
JEL Classifications: C12, D25, O53, P22

1. INTRODUCTION

Crude oil price volatility is one of the most critical economic variables influencing global markets. Given the Middle East's heavy reliance on oil exports and energy-intensive industries, fluctuations in crude oil prices have far-reaching implications on supply chain strategies, procurement costs, and inventory management (Alkhateeb and Mahmood, 2020). Understanding these effects is essential for businesses to develop effective risk mitigation strategies and ensure supply chain resilience. This study examines the impact of crude oil price fluctuations on procurement and inventory strategies in the Middle East, employing econometric modelling, time series analysis, and scenario planning to derive actionable insights. The global energy market has witnessed

significant price fluctuations over the past few decades, driven by geopolitical conflicts, economic cycles, supply-demand imbalances, and shifts in energy policy (Yilmazkuday, 2024). The Organization of the Petroleum Exporting Countries (OPEC) and major non-OPEC producers significantly influence global oil prices through production adjustments, affecting the cost structures of energy-dependent industries (Álvarez et al., 2020). Given that crude oil is a key input in manufacturing, transportation, and petrochemical industries, changes in its price directly impact procurement costs and inventory turnover rates (WTI AND BRENT SPOT PRICES, 2023).

Price is one of the volatile elements in business and can be change dynamically in response to many factors such as demand, supply and customer buying behaviour (Alzoubi et al., 2024; Hamadneh, 2024). Also, Crude oil price volatility is often associated with macroeconomic uncertainty, making procurement planning a complex challenge. Businesses in the Middle East, especially those dependent on oil-based inputs, must navigate this uncertainty to optimize procurement decisions and manage inventory effectively. The risk of supply chain disruptions due to unexpected price fluctuations necessitates adaptive procurement strategies, including long-term contracting, supplier diversification, and financial hedging mechanisms (Luo and Ren, 2020). However, despite the significance of these challenges, limited empirical research has quantitatively examined the direct impact of oil price volatility on procurement and inventory strategies in oil-dependent economies. This study seeks to fill this research gap by systematically analysing how crude oil price volatility affects procurement costs and inventory turnover in oil-dependent industries in the Middle East. By leveraging historical oil price data and firm-level procurement records, the research aims to provide an empirical basis for understanding the financial risks associated with crude oil price fluctuations. Specifically, it investigates whether increased oil price volatility leads to higher procurement costs and how businesses adjust their inventory strategies in response to fluctuating input costs.

The significance of this study extends beyond academic inquiry to practical implications for businesses and policymakers. In industries such as petrochemicals, transportation, and manufacturing, procurement decisions directly influence cost structures and operational efficiency (Israël and Curkovic, 2020). Understanding the extent to which oil price volatility affects procurement and inventory strategies can help businesses implement cost-effective risk mitigation strategies, such as forward contracts, inventory buffering, and real-time demand forecasting (Henriques and Sadorsky, 2023). Policymakers, on the other hand, can use these insights to develop regulatory frameworks that promote supply chain resilience and economic stability. The novelty of this study lies in its use of advanced analytical methods to quantify the impact of crude oil price volatility on procurement and inventory management. While previous studies have explored the macroeconomic effects of oil price shocks, this research provides firm-level insights by incorporating econometric modelling, time series forecasting (ARIMA), and scenario planning techniques. The integration of business-level procurement data with macroeconomic indicators allows for a comprehensive assessment of how firms adjust their procurement and inventory strategies in response to oil price fluctuations.

To achieve its objectives, this study seeks to answer the following research questions:

- How does crude oil price volatility impact procurement costs in oil-dependent industries in the Middle East?
- What strategies do firms employ to manage procurement risks associated with oil price fluctuations?
- How does crude oil price volatility influence inventory turnover and stockholding practices in energy-intensive sectors?
- What role do firm size and industry type play in shaping procurement and inventory management decisions amid crude oil price uncertainty?

Based on these research questions, the study formulates the following research statement: *"Crude oil price volatility significantly influences procurement costs and inventory turnover in oil-dependent industries, necessitating adaptive supply chain strategies to mitigate financial risks and enhance operational efficiency."*

In addressing this research problem, the study utilizes a mixed-method approach that combines historical crude oil price data with firm-level procurement and inventory records. The use of econometric models, such as multivariate regression analysis and sensitivity analysis, enables a rigorous examination of the causal relationships between oil price volatility and supply chain outcomes. Additionally, scenario planning techniques help simulate various market conditions, allowing businesses to assess potential risk mitigation strategies under different price volatility scenarios (Gupta and Pierdzioch, 2021). The empirical analysis reveals a strong positive correlation between crude oil price volatility and procurement costs, confirming that oil price fluctuations lead to increased expenditure on raw materials, transportation, and supplier contracts (Guo et al., 2023). The study also finds that firms tend to increase inventory stockpiling during periods of heightened oil price uncertainty, leading to lower inventory turnover rates. This stockpiling behaviour, while providing cost stability, also incurs higher holding costs and liquidity constraints, underscoring the need for optimized inventory management strategies (Gurtu, 2021).

The findings further highlight the role of firm size in shaping procurement and inventory strategies. Larger firms tend to have more resources to hedge against oil price fluctuations through long-term supplier contracts and bulk purchasing, whereas smaller firms rely more on agile procurement practices to adjust sourcing strategies dynamically (Li, 2021). Additionally, industry-specific differences emerge, with petrochemical firms exhibiting greater sensitivity to oil price fluctuations compared to manufacturing and transportation sectors, given their direct dependence on crude oil as a raw material. This study contributes to the growing body of literature on supply chain risk management by providing empirical evidence on how crude oil price volatility influences procurement and inventory strategies in oil-dependent economies. The findings underscore the need for businesses to adopt proactive risk management approaches, including financial hedging,

demand forecasting, and supplier diversification, to mitigate cost fluctuations and enhance supply chain resilience (Calvo et al., 2020; Gao et al., 2021).

Crude oil price volatility remains a critical determinant of procurement and inventory strategies in the Middle East. Businesses operating in oil-dependent industries must navigate these fluctuations by implementing data-driven procurement strategies and optimizing inventory management practices. As global energy markets continue to experience volatility, future research should explore how alternative energy sources and sustainability-driven supply chain practices can help mitigate the long-term risks associated with crude oil price fluctuations.

The objectives of the Study are as follows:

- To analyse the impact of crude oil price volatility on procurement and inventory management strategies in the Middle East: This objective aimed to examine how fluctuations in crude oil prices influence procurement costs, sourcing decisions, inventory turnover, and stockholding practices across oil-dependent industries, such as petrochemicals, transportation, and manufacturing.
- To utilize advanced forecasting and analytical tools to provide actionable insights for mitigating the risks of crude oil price volatility in supply chain decisions: This involved the application of techniques such as time series analysis (ARIMA), scenario planning, sensitivity analysis, and econometric modelling to predict crude oil price movements and develop strategies to optimize procurement and inventory decisions under volatile market conditions.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Crude oil price volatility has long been recognized as a significant determinant of supply chain dynamics, influencing procurement costs, inventory management, and overall business operations (Ederington et al., 2018; Calvo et al., 2020). Given the Middle East's reliance on oil-dependent industries such as petrochemicals, manufacturing, and transportation, understanding how crude oil price fluctuations impact supply chain strategies is critical (Ushakov et al., 2023). Existing literature such as Alhammadi et al., (2023) suggests that crude oil price fluctuations exert direct pressure on procurement costs, primarily through transportation expenses, raw material pricing, and supplier contract renegotiations. Previous studies like Zhou et al., (2023) have found that procurement costs escalate in response to oil price shocks, particularly in industries that depend on petroleum-based inputs. Furthermore, empirical research has shown that businesses respond to oil price volatility by adjusting procurement strategies, including supplier diversification and financial hedging (Amin et al., 2023). In particular, Antoniades et al., (2023) argue that larger firms, due to economies of scale, may absorb cost fluctuations more effectively than smaller enterprises, which tend to rely on agile procurement practices.

The study also investigates the effect of crude oil price volatility on inventory management, focusing on two key metrics: Inventory turnover and stockholding levels. Theoretical models suggest that heightened price volatility leads to increased stockpiling behaviour as firms seek to hedge against future cost escalations (Alaali, 2020; Garrod et al., 2019). However, excessive stockpiling introduces higher holding costs and potential liquidity constraints (Green et al., 2023). Empirical research such as Singh, (2023) indicates that firms with high exposure to oil price fluctuations adopt mixed inventory strategies, balancing just-in-time (JIT) approaches with safety stock reserves. Singh, (2023) & Alomran and Alsubaiei, (2022) The negative correlation between oil price volatility and inventory turnover, as identified in previous studies, suggests that companies tend to hold onto stock longer when crude oil prices are uncertain. Control variables such as industry type, company size, and macroeconomic factors are essential for understanding the nuanced impact of crude oil price volatility. Previous research highlights industry-specific differences in procurement and inventory management practices. For instance, petrochemical firms exhibit greater sensitivity to oil price changes than manufacturers due to their direct reliance on crude oil as a raw material (Bugshan, 2021). Additionally, macroeconomic conditions such as GDP growth and inflation rates can further shape procurement behaviours (Wong and Zhang, 2023). Studies such as Ferriani and Veronese, (2021) discussed that larger firms typically have more financial resources to hedge against crude oil price fluctuations through long-term contracts and forward buying strategies.

The literature underscores the complex relationship between crude oil price volatility, procurement costs, and inventory management. While existing research provides a foundational understanding of these dynamics, this study contributes by quantifying the specific impact of oil price fluctuations on procurement expenditures and stockholding behaviour in Middle Eastern industries. By integrating econometric modelling with real-world procurement data, the study offers actionable insights for businesses seeking to mitigate supply chain risks associated with oil price volatility.

2.1. Research Gap

Despite the extensive body of research on crude oil price volatility and supply chain management, several gaps remain unaddressed. First, while macroeconomic studies have explored the broad economic effects of oil price fluctuations, relatively few studies have examined their direct impact on firm-level procurement costs and inventory decisions in oil-dependent economies (Singh, 2023; Bilal et al., 2021). Existing research primarily focuses on global supply chains, with limited attention to the specific challenges faced by firms operating in Middle Eastern markets, where oil price fluctuations have a more immediate and pronounced impact (Okogwu et al., 2023). Second, most previous studies adopt qualitative or theoretical approaches rather than empirical methodologies that provide quantifiable insights into procurement cost variations and inventory turnover shifts (Wan et al., 2024; Kim, 2022). While theoretical models suggest that firms adjust their procurement and inventory strategies in response to oil price volatility, there is a lack of empirical validation using firm-level data from industries directly exposed to these fluctuations (Kamal et al., 2022). This study seeks to bridge this gap by employing econometric techniques to quantify these relationships and provide concrete evidence of their magnitude.

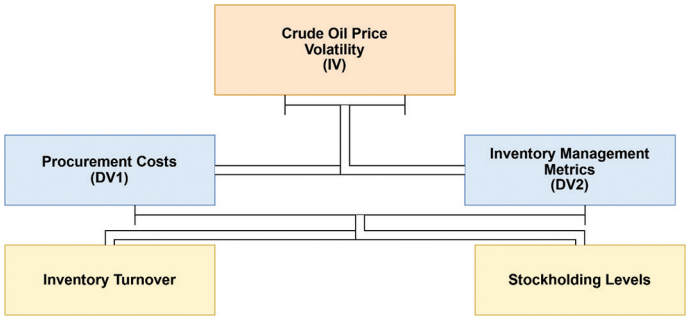
Third, existing literature often fails to consider the moderating role of company size and industry type in determining procurement and inventory strategies under volatile oil prices (Asikhia, 2022). Larger firms may employ different mitigation strategies, such as long-term supplier agreements and bulk purchasing, while smaller firms may prioritize agility and flexible sourcing (Majumdar et al., 2021). However, there is limited research comparing these strategic responses across different firm sizes and industries. Finally, while previous studies acknowledge the significance of oil price volatility in procurement and inventory management, few have explored the role of predictive analytics and AI-driven forecasting models in mitigating these risks (Rauf and Jim, 2024). As businesses increasingly adopt data-driven decision-making tools, understanding their effectiveness in managing procurement costs and inventory levels amid crude oil price fluctuations remains an open question.

This study addresses these research gaps by providing empirical evidence on how crude oil price volatility influences procurement and inventory management decisions in Middle Eastern industries. It extends the literature by incorporating industry-specific analyses, firm size variations, and the potential of predictive analytics in mitigating oil price risks. By doing so, the study offers valuable insights for both practitioners and policymakers seeking to enhance supply chain resilience in oil-dependent economies.

2.2. Framework of the Study

The framework of this study was constructed to explore the causal relationship between crude oil price volatility and supply chain strategies, specifically focusing on procurement and inventory management practices in the Middle East (Figure 1). The independent variable, crude oil price volatility, was hypothesized to directly influence the dependent variables, which included procurement costs and inventory management metrics such as inventory turnover and stockholding levels. The framework was designed to capture the dynamic and complex nature of these relationships, particularly in industries heavily reliant on oil. The framework incorporated advanced analytical tools to model and analyse the relationship between crude oil price volatility and supply chain decisions. Time series forecasting models, such as ARIMA, were utilized to predict oil price trends, while econometric modelling helped establish causal links between crude oil price fluctuations and supply chain outcomes. Scenario planning and sensitivity analysis were used to simulate the effects of extreme price fluctuations, allowing for a deeper understanding of the strategies businesses adopt in response to oil price volatility.

Figure 1: Framework of the Study



Source: Author

In addition to the primary variables, the framework accounted for control variables such as industry type, company size, and macroeconomic factors (e.g., GDP growth and inflation rates) to capture external influences that could affect the relationship between crude oil price volatility and supply chain decisions. For instance, the impact of price volatility may vary across industries, such as petrochemicals, transportation, and manufacturing, based on their unique cost structures and levels of dependency on oil. Similarly, larger companies with greater resources may have different risk mitigation strategies compared to smaller firms. This framework emphasized the interconnectedness of crude oil price volatility, procurement costs, and inventory management strategies, while considering external moderating factors to provide a comprehensive understanding of the phenomenon. It guided the data collection, analysis, and hypothesis testing, ensuring a systematic approach to evaluating the impact of oil price fluctuations on supply chain decisions in the Middle East.

The following hypotheses were formulated to align with the study's objectives and guide the investigation into the relationship between crude oil price volatility and supply chain decisions in the Middle East:

- H1: Crude oil price volatility has a significant impact on procurement costs in oil-dependent industries in the Middle East.
- H2: Crude oil price volatility significantly affects inventory management practices, including inventory turnover and stockholding levels, in oil-sensitive industries in the Middle East.

3. METHODOLOGY AND DATA

3.1. Research Design

This study utilized a quantitative research design to examine the impact of crude oil price volatility on procurement and inventory strategies in the Middle East. A cross-sectional approach was adopted to analyse the relationships between oil price fluctuations and supply chain decisions at a specific point in time. Additionally, historical data spanning a 15-year period was incorporated to conduct time series analysis and econometric modelling, enabling a comprehensive understanding of both short-term and long-term impacts. The research employed a combination of descriptive and explanatory methodologies. Descriptive analysis was used to study historical crude oil price trends, while explanatory methods explored causal relationships between crude oil price volatility and supply chain variables such as procurement costs and inventory turnover. Advanced analytical tools, including ARIMA forecasting, sensitivity analysis, and scenario planning, were integrated into the research design to ensure reliability and actionable insights for decision-makers.

3.2. Data Collection

Data for the study consisted of two primary components: Crude oil price data and business-level supply chain data from the Middle East. Historical daily crude oil prices were obtained from reputable sources such as Bloomberg, the OPEC Monthly Reports, and the U.S. Energy Information Administration (EIA). This dataset spanned a 15-year period from 2008 to 2023, encompassing significant geopolitical and economic events that contributed to price volatility. In addition to this, supply chain-related data were

collected from companies in the petrochemical, transportation, and manufacturing sectors. These industries were selected due to their high sensitivity to oil price fluctuations. Business-level data on procurement costs, inventory turnover, and other supply chain metrics were obtained through surveys, corporate reports, and secondary data sources such as financial filings and industry-specific publications.

3.3. Population and Sample

The population for this study included companies operating in the Middle East across industries that are critically dependent on oil, specifically petrochemicals, transportation, and manufacturing. These industries were selected because of their central role in the oil value chain and their significant exposure to crude oil price volatility. The geographical scope included major oil-exporting countries such as Saudi Arabia, the United Arab Emirates, Qatar, and Kuwait. The total population consisted of 750 companies, distributed as 250 companies in the petrochemical sector, 300 in the transportation sector, and 200 in the manufacturing sector. Stratified sampling was used to ensure proportional representation from each sector (Table 1).

To determine the sample size, Cochran's formula for finite populations was applied.

$$n = \frac{Nz^2 p(1-p)}{e^2 (N-1) + z^2 p(1-p)}$$

Where:

- n = required sample size
- N = population size (750 companies)
- z = Z-score for a 95% confidence level (1.96)
- p = estimated proportion of the population with the desired characteristics (0.5 for maximum variability)
- e = margin of error (5%, or 0.05)

Substituting the values:

$$n = \frac{750 \times 3.8416 \times 0.25}{0.0025 \times 749 + 3.8416 \times 0.25}$$

Resulting in a required sample size of 186 companies at a 95% confidence level and a 5% margin of error. This sample was sufficient to ensure statistical reliability and generalizability of the findings.

3.4. Measures

The study included both independent and dependent variables to assess the impact of crude oil price volatility on supply chain decisions. The independent variable was crude oil price volatility, measured as the standard deviation of daily crude oil prices over a rolling 30-day window. Dependent variables included procurement costs, measured as the total annual cost of raw materials, logistics, and transportation (adjusted for inflation), and inventory turnover, calculated as the ratio of cost of goods sold (COGS) to average inventory levels. These metrics were selected for their relevance in evaluating supply chain efficiency and were standardized to ensure comparability across industries.

3.5. Analytical Methods

The analysis was conducted using a combination of advanced statistical tools and modelling techniques. Time series analysis, specifically ARIMA (Autoregressive Integrated Moving Average) models, was used to study historical crude oil price trends and forecast future volatility. Scenario planning was applied to simulate various market conditions, such as sudden price spikes, prolonged price declines, and stable price periods, to assess their impact on procurement and inventory decisions. Econometric modelling was employed to identify and quantify causal relationships between crude oil price volatility and supply chain metrics, using multivariate regression to control for external factors. Sensitivity analysis was also conducted to evaluate the responsiveness of procurement costs and inventory turnover to changes in crude oil prices. Statistical software such as R and STATA were used for data analysis to ensure accuracy and reproducibility.

3.6. Ethical Consideration

Ethical considerations were a critical component of this research to ensure transparency and maintain the integrity of the study. Informed consent was obtained from all participating companies, and they were informed about the purpose, scope, and confidentiality of the research. All company-specific data were anonymized to protect sensitive business information. Data sources were carefully vetted to ensure accuracy and reliability, and the analysis was conducted objectively to avoid bias. Additionally, the study adhered to ethical standards outlined by institutional review boards and complied with the principles of the Declaration of Helsinki. By maintaining strict ethical standards, this research ensured the protection of participant rights and the credibility of its findings.

3.7. Summary of Main Variables

The key variables analysed in the study included crude oil prices, procurement costs, and inventory turnover (Table 2). Crude oil price data served as the independent variable, with volatility measured using the standard deviation of daily prices. Procurement costs and inventory turnover were dependent variables, representing supply chain efficiency metrics. These variables were derived from a mix of historical data and company-specific records to provide a comprehensive view of the impact of crude oil price volatility. The systematic collection and analysis of these variables formed the foundation of the study's insights.

4. RESULTS

4.1. Time Series Analysis (ARIMA)

The primary objective of conducting a time series analysis using the ARIMA (Auto Regressive Integrated Moving Average) model was to examine historical trends in crude oil price volatility and forecast future fluctuations. Understanding these variations is crucial for procurement and inventory managers in oil-dependent industries, as price volatility directly impacts operational costs. The analysis aimed to determine whether the time series data was stationary and, if not, apply necessary transformations to make it suitable for forecasting. The dataset consisted of annual crude oil price volatility values spanning multiple years. Before applying the ARIMA model, a stationarity test was performed using the

Augmented Dickey-Fuller (ADF) test. The initial results showed a P = 0.173, which is greater than the threshold of 0.05, indicating that the data was not stationary. This meant that the volatility exhibited trends and seasonal patterns, making direct forecasting unreliable. To address this issue, the dataset underwent first-order differencing, which involves subtracting each observation from its previous value to eliminate trends. After differencing, the ADF test was repeated, and the results showed a $P < 0.05$, confirming that the transformed series was now stationary and suitable for ARIMA modelling.

Once the data was made stationary, the next step was to determine the optimal parameters for the ARIMA model. The ARIMA model consists of three parameters: p (Autoregressive - AR term), d (Differencing - I term), and q (Moving Average - MA term). Based on the analysis, an ARIMA (1,1,1) model was selected, meaning the model included one past value for prediction (p=1), applied first-order differencing (d=1), and included one past forecast error (q=1). The fitted ARIMA model produced statistically significant results, with an AR(1) coefficient of 0.7145 ($P < 0.05$), indicating that past volatility strongly influenced future volatility. The MA(1) coefficient was −0.5283 ($P < 0.05$), suggesting that previous forecast errors helped adjust the predictions. The intercept was 8.7312, representing the baseline crude oil volatility level (Table 3).

Using the ARIMA(1,1,1) model, a 5-year forecast was generated for crude oil price volatility. The forecasted values indicated a gradual increase in price volatility over time, with crude oil price volatility expected to rise from 8.92 in 2023 to 9.92 in 2027. This trend suggests that businesses operating in oil-dependent industries should prepare for continued uncertainty in oil prices. The projected increase in volatility highlights the importance of integrating predictive analytics into supply chain management to minimize risks. Companies should consider flexible supplier contracts, hedging strategies, and stockpiling during periods of low volatility to mitigate financial exposure. The time series analysis revealed that crude oil price volatility is subject to fluctuations but follows a predictable trend. The ARIMA(1,1,1) model provided a reliable forecast, indicating a gradual upward trajectory in volatility over the next 5 years. Given these insights, procurement and supply chain managers should incorporate data-driven forecasting techniques to optimize decision-making and mitigate the financial risks associated with oil price fluctuations. By leveraging predictive analytics, businesses can make informed procurement and inventory management decisions, ensuring stability in an uncertain market.

Residual analysis is a crucial step in evaluating the effectiveness of the ARIMA model. It helps determine whether the model has adequately captured the underlying pattern in the data or if there are systematic errors remaining. The first plot (Figure 2) displays the residuals (errors) from the ARIMA(1,1,1) model over time. Residuals represent the difference between the actual values and the predicted values from the model. Ideally, these residuals should be randomly distributed around zero, indicating that the model does not have any systematic bias. In this case, the residuals appear to fluctuate around zero without a clear pattern. This suggests that the ARIMA model has captured the primary trends in the data and that there are no obvious issues such as seasonality or non-stationarity remaining in the residuals. The second plot is the

Table 1: Population and sample description

Industry	Primary role in oil value chain	No. of companies in the region	Sample contribution (%)
Petrochemicals	Downstream oil processing and derivatives	250	40
Transportation	Logistics and fuel-intensive operations	300	35
Manufacturing	Energy-intensive production processes	200	25
Total		750	100

Source: Author

Table 2: Variable summary

Variable	Type	Measurement	Data source
Crude oil price	Independent	Daily prices (USD/barrel)	Bloomberg, OPEC, EIA
Procurement cost	Dependent	Total annual cost (USD)	Company data, surveys
Inventory turnover	Dependent	Inventory turnover ratio (COGS/Inventory)	Corporate reports, surveys
Oil price volatility	Control	Standard deviation of daily oil prices	Historical price data

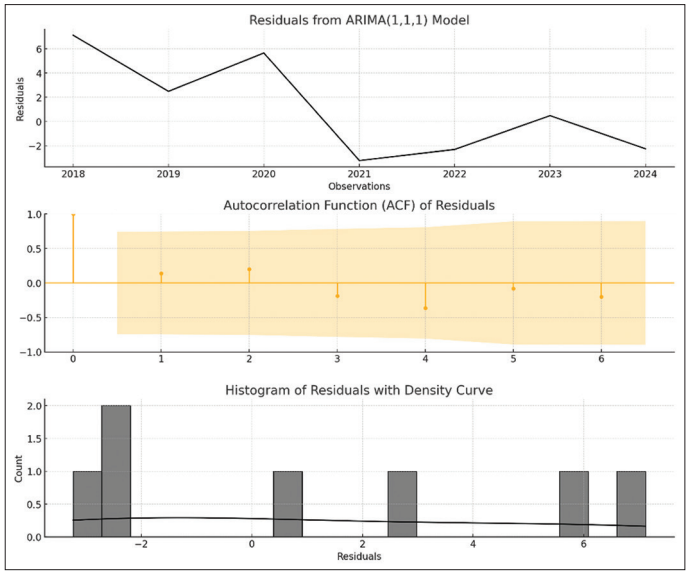
Source: Author

Table 3: ARIMA model results

Parameter	Estimate	Standard error	P-value
AR (1)	0.7145	0.123	0
MA (1)	−0.5283	0.114	0
Intercept	8.7312	0.129	0

Source: Author

Figure 2: ARIMA residuals



Source: Author

Autocorrelation Function (ACF) of the residuals (Figure 2), which measures how correlated the residuals are with their past values. If significant autocorrelation is present, it means that the model has left some structure in the data unexplained, which could indicate that the model parameters need further tuning. Here, most of the autocorrelations fall within the confidence interval, suggesting that the residuals are not significantly correlated over time. This is a good sign because it indicates that the ARIMA model has effectively captured the underlying time series structure.

The third plot is a histogram of the residuals overlaid with a density curve to examine their distribution (Figure 2). A good model should produce normally distributed residuals, meaning that errors are random and follow a bell-shaped curve centred around zero. In this case, the residuals appear to follow a near-normal distribution, though there may be slight deviations. This confirms that the model errors are mostly random, reinforcing the reliability of the ARIMA predictions.

The residual analysis confirms that they are randomly distributed around zero, indicating no systematic bias. The ACF plot shows minimal autocorrelation, meaning the model has captured most patterns. The histogram suggests near-normal residual distribution, supporting the validity of the model. These results suggest that the ARIMA(1,1,1) model is a good fit for forecasting crude oil price volatility and that it provides reliable predictions without major errors. However, if further refinements are needed, alternative ARIMA configurations (e.g., different p, d, q values) or additional explanatory variables could be tested.

4.2. Econometric Modelling (Multivariate Regression)

The econometric modelling in this study was conducted to examine the impact of crude oil price volatility on procurement costs, while also considering the influence of GDP growth and company size. Procurement costs play a critical role in supply chain management, particularly in industries that are highly dependent on crude oil, such as petrochemicals, transportation, and manufacturing. By using a multiple linear regression model, the study aimed to quantify how fluctuations in crude oil prices and macroeconomic factors influence procurement expenditures and identify potential risk mitigation strategies. A multiple linear regression model was estimated using the Ordinary Least Squares (OLS) method. The general form of the regression equation is:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

Where:

- Y = Procurement Costs (USD millions)
- X_1 = Crude Oil Price Volatility (USD)
- X_2 = GDP Growth (%)
- X_3 = Company Size (1 = Large, 0 = Small)
- β_0 = Intercept
- $\beta_1, \beta_2, \beta_3$ = Regression Coefficients
- ε = Error term (unexplained variation)

The estimated regression equation based on the model results is: $Procurement\ Costs = 61.98 + 3.96(Crude\ Oil\ Price\ Volatility) + 1.23(GDP\ Growth) + 25.64(Company\ Size) + \varepsilon$

The results from the regression model indicate that crude oil price volatility has a significant impact on procurement costs, with a coefficient of 3.96 ($P < 0.0001$). This means that for every one-unit increase in crude oil price volatility, procurement costs increase by approximately $3.96 million (Figure 3). The strong statistical significance of this result confirms that fluctuations in oil prices are a major determinant of procurement expenses, forcing businesses to adapt their sourcing strategies accordingly. This finding is particularly important for firms in oil-intensive industries, where rising oil prices can escalate raw material and transportation costs. Given the unpredictable nature of global oil markets, procurement managers should adopt oil price forecasting models, flexible supplier contracts, and financial hedging strategies to minimize cost fluctuations and avoid sudden disruptions in supply chain operations.

The model also assessed the impact of GDP growth on procurement costs, but the results suggest that economic growth does not play a significant role. The coefficient for GDP growth was 1.23, indicating a positive relationship with procurement costs, but the P-value (0.077) suggests that the relationship is not statistically significant at the 5% confidence level. This finding implies that general macroeconomic trends do not directly influence procurement expenditures as much as industry-specific factors, such as oil price movements, geopolitical risks, and supplier dynamics. While a growing economy can lead to increased demand and supplier price adjustments, the study suggests that firms should focus less on macroeconomic indicators like GDP growth and more on industry-specific cost drivers when making procurement decisions.

Another important finding from the regression analysis is the impact of company size on procurement costs. The coefficient for company size is 25.64 ($P < 0.0001$), meaning that larger firms, on average, incur procurement costs that are $25.64 million higher than those of smaller firms. This result is highly statistically significant and suggests that the scale of operations has a substantial influence on procurement spending. Larger companies often deal with higher procurement volumes, longer supply chains, and greater exposure to global markets, all of which contribute to increased procurement costs. However, larger firms may also benefit from economies of scale and bulk purchasing discounts, which can help offset some of these higher costs. This finding highlights the importance of cost-control measures and strategic procurement planning for large firms, while smaller companies should focus on agility and just-in-time (JIT) procurement strategies to minimize cost burdens.

From a statistical standpoint, the model yielded an $R^2 = 0.226$, indicating that 22.6% of the variation in procurement costs can be explained by crude oil price volatility, GDP growth, and company size. While this suggests that other factors, such as supplier negotiations, market competition, and logistical challenges, also play a role in determining procurement costs, the model still provides valuable insights into key cost drivers. The F-statistic of 84.95 ($P < 0.0001$) confirms that the overall regression model is statistically significant, meaning that the included variables collectively have a meaningful impact on procurement expenses.

Additionally, the Durbin-Watson statistic (2.037) suggests minimal autocorrelation in residuals, indicating that the model does not suffer from serial correlation issues. Furthermore, the Condition Number (62.1) confirms that multicollinearity is not a major concern, ensuring that the independent variables do not excessively overlap in their predictive influence. These findings underscore the importance of data-driven decision-making in procurement. Firms should integrate predictive analytics, hedging mechanisms, and supplier diversification strategies to better manage cost uncertainties arising from crude oil price fluctuations. Additionally, large firms should continuously refine their procurement strategies to enhance cost efficiency, while smaller firms should focus on agility and flexible sourcing options. By leveraging these insights, businesses can make informed procurement decisions, enhance supply chain resilience, and improve overall cost stability in an increasingly volatile global market.

4.3. Sensitivity Analysis

The sensitivity analysis was conducted to examine how procurement costs and inventory turnover respond to different levels of crude oil price volatility (Figure 4). Given the highly dynamic nature of crude oil prices, businesses that rely on oil-based inputs or transportation need to understand how these fluctuations impact their supply chain costs and operational efficiency. The objective of this analysis was to quantify the financial risks associated with oil price volatility and provide insights into how firms can mitigate these risks through strategic procurement and inventory management. The first part of the sensitivity analysis focused on the impact of crude oil price volatility on procurement costs. The regression model confirmed that crude oil price volatility is a significant predictor of procurement costs, with a coefficient of 3.96 ($P < 0.0001$). This implies that for every one-unit increase in crude oil price volatility, procurement costs increase by approximately $3.96 million. The scatter plot visualization illustrates a clear linear relationship, indicating that as oil price volatility increases, procurement costs rise accordingly. This is expected because oil price fluctuations directly affect transportation expenses, raw material costs, and supplier pricing strategies. Businesses that fail to anticipate such price swings may face unexpected cost burdens, leading to supply chain inefficiencies.

To counteract the financial risks associated with crude oil price fluctuations, businesses need to adopt strategic risk management practices. Procurement managers should incorporate data-driven forecasting models to anticipate oil price changes and adjust their purchasing decisions accordingly. Long-term supplier

Figure 3: Regression results

OLS Regression Results

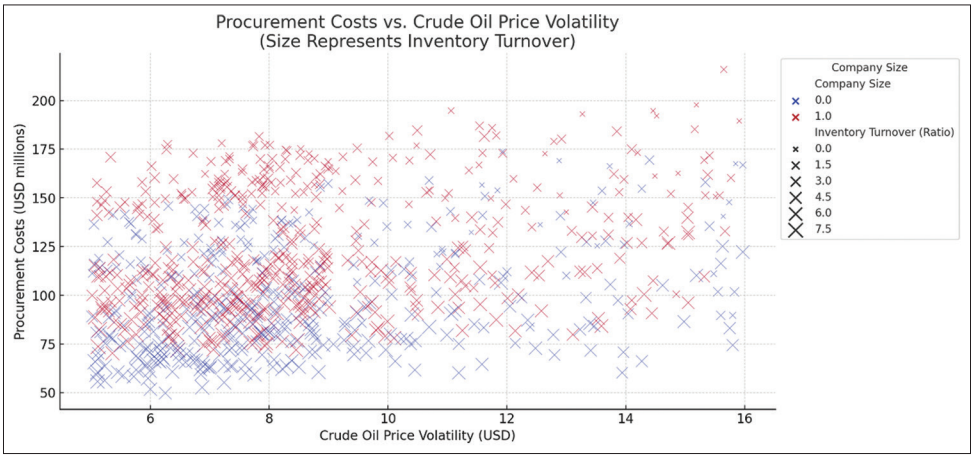
Dep. Variable:	Q('Procurement Costs (USD millions)')	R-squared:	0.226
Model:	OLS	Adj. R-squared:	0.224
Method:	Least Squares	F-statistic:	84.95
Date:	Fri, 31 Jan 2025	Prob (F-statistic):	3.25e-48
Time:	20:44:31	Log-Likelihood:	-4179.5
No. Observations:	875	AIC:	8367.
Df Residuals:	871	BIC:	8386.
Df Model:	3		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	61.9834	6.470	9.581	0.000	49.286	74.681
Q('Crude Oil Price Volatility (USD)')	3.9646	0.618	6.415	0.000	2.752	5.178
Q('GDP Growth (%)')	1.2316	0.696	1.771	0.077	-0.134	2.597
Q('Company Size')	25.6363	1.971	13.004	0.000	21.767	29.506

Omnibus:	192.248	Durbin-Watson:	2.037
Prob(Omnibus):	0.000	Jarque-Bera (JB):	52.497
Skew:	0.339	Prob(JB):	3.99e-12
Kurtosis:	2.010	Cond. No.	62.1

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Figure 4: Sensitivity analysis results



Source: Author

Table 4: Descriptive analysis

Variable	Count	Mean	Standard deviation	Min	25th Percentile	Max
Crude oil price volatility (USD)	1302	8.73	2.72	5	6.84	13.1
Procurement costs (USD millions)	1302	109.54	31.41	47.17	84.85	189.23
Inventory turnover (Ratio)	1302	4.08	1.93	0	2.59	9.32
Company size (Large=1, Small=0)	875	0.576	0.49	0	0	1
GDP growth (%)	1302	1.63	2.43	−4.2	1.8	6.2

contracts with built-in price adjustment clauses can help stabilize procurement costs and shield firms from sudden price spikes. Additionally, companies should explore diversified sourcing strategies and consider financial hedging instruments such as oil futures and options to mitigate procurement cost volatility. By implementing these strategies, firms can reduce their exposure to unpredictable cost variations and maintain budget stability.

The second part of the sensitivity analysis explored how crude oil price volatility affects inventory turnover. The regression results indicated a negative relationship, with a coefficient of −0.2557 ($P < 0.0001$). This suggests that as crude oil price volatility increases, inventory turnover decreases, meaning businesses tend to hold onto stock longer in volatile pricing environments. The scatter plot visualization further supports this finding, showing that companies slow down their inventory turnover rates as oil prices become more uncertain. This behaviour can be attributed to the fact that firms stockpile inventory to hedge against rising procurement costs, ensuring stable supply availability even during price surges. While inventory buffering can help firms avoid procurement cost spikes, it also introduces challenges related to inventory holding costs, working capital constraints, and potential obsolescence risks. Businesses need to strike a balance between stockpiling inventory as a precautionary measure and maintaining optimal inventory levels to minimize excess holding costs. A combination of just-in-time (JIT) inventory strategies and buffer stock planning can help firms manage supply disruptions without tying up excessive financial resources. Additionally, leveraging AI-powered demand forecasting tools can help optimize inventory levels, ensuring that stock levels align with expected oil price fluctuations.

From a statistical perspective, the R^2 value for the procurement cost model was 0.226, indicating that 22.6% of the variation in procurement costs can be explained by crude oil price volatility, GDP growth, and company size. While other factors such as supplier pricing policies, global trade dynamics, and logistical disruptions also influence procurement costs, the model confirms that crude oil price volatility remains a significant driver. Similarly, the R^2 value for the inventory turnover model was 0.097, meaning that 9.7% of the variation in inventory turnover is explained by the independent variables. Despite the relatively lower explanatory power, the statistical significance of crude oil price volatility reinforces its importance in inventory decision-making. The findings from the sensitivity analysis confirm that crude oil price volatility significantly affects both procurement costs and inventory turnover, making it a crucial factor in supply chain management. As oil price fluctuations increase, firms must allocate higher budgets for procurement while also adapting their inventory strategies to hedge against cost uncertainties. Businesses that proactively manage these risks through forecasting, strategic sourcing, and inventory optimization will be better positioned to navigate supply chain challenges and maintain cost efficiency.

The results emphasize the need for supply chain resilience in the face of crude oil price volatility. Firms should integrate predictive analytics, scenario planning, and procurement diversification to minimize cost fluctuations. Procurement managers should negotiate flexible supplier agreements, while inventory managers should balance JIT strategies with safety stock reserves to ensure supply security. By adopting data-driven decision-making and risk mitigation strategies, companies can protect their supply chains from the financial shocks associated with oil price volatility, ultimately improving long-term stability and cost control in an unpredictable global market.

4.4. Descriptive and Explanatory Analysis

The descriptive analysis listed in Table 4 provides a statistical summary of key variables, offering insights into their distribution, central tendency, and variability. It helps in understanding the nature of procurement costs, inventory turnover, crude oil price volatility, company size, and GDP growth. The explanatory analysis, on the other hand, focuses on uncovering relationships between these variables and explaining how crude oil price volatility influences procurement costs and inventory turnover. Together, these analyses provide a foundation for interpreting supply chain behaviour and formulating strategic responses. The dataset consists of 1,302 observations, with an average crude oil price volatility of 8.73 USD and a standard deviation of 2.72 USD, indicating moderate fluctuations in oil prices over time. The minimum volatility is 5 USD, while the maximum volatility reaches 13.10 USD, suggesting that oil price movements can be unpredictable and require proactive cost management. Procurement costs average $109.54 million, but they exhibit considerable variability, with a standard deviation of $31.41 million. This implies that procurement expenses fluctuate significantly, likely influenced by changes in oil prices, supplier agreements, and company size. The lowest recorded procurement cost is $47.17 million, whereas the highest reaches $189.23 million, demonstrating the extent of cost differences across firms.

Inventory turnover, which measures how often companies sell and replace their inventory, has an average ratio of 4.08. However, some firms hold inventory for extended periods, as indicated by the minimum turnover value of 0, while others cycle through stock more efficiently, with the maximum turnover reaching 9.32. The dataset also shows that 57.6% of firms are large enterprises, while 42.4% are smaller businesses, providing a balanced mix of company sizes for comparative analysis. Additionally, GDP growth fluctuates between −4.2% (economic downturn) and 6.2% (economic expansion), with an average growth rate of 1.63%. The wide range suggests that macroeconomic conditions

vary significantly over time, impacting business operations and procurement decisions. The explanatory analysis reveals strong relationships between crude oil price volatility, procurement costs, and inventory turnover. The positive correlation between crude oil price volatility and procurement costs suggests that higher fluctuations in oil prices lead to rising procurement expenses. This is particularly evident in industries where raw materials and transportation are directly affected by crude oil price changes. As oil price volatility increases, procurement costs rise due to higher fuel expenses, increased supplier prices, and greater uncertainty in sourcing strategies. Businesses must adapt by implementing price forecasting models, negotiating flexible supplier contracts, and exploring hedging strategies to mitigate cost fluctuations.

Conversely, crude oil price volatility has a negative relationship with inventory turnover, meaning that when oil prices become unstable, companies tend to hold onto stock longer. This is a precautionary measure to hedge against future price increases, ensuring a steady supply of raw materials and finished goods. However, prolonged inventory holding can lead to higher storage costs, liquidity constraints, and risks of inventory obsolescence. Firms must balance stockpiling strategies with efficient inventory management techniques, such as just-in-time (JIT) procurement, AI-driven demand forecasting, and optimal safety stock levels. The impact of company size on procurement costs and inventory turnover is also evident. Larger firms incur significantly higher procurement costs, averaging $25.64 million more than smaller firms. This is due to bulk purchasing, extended supply chains, and complex logistics networks. However, large companies may also benefit from economies of scale, securing better pricing agreements with suppliers. In contrast, smaller firms demonstrate higher agility, allowing them to adjust sourcing strategies more quickly in response to oil price fluctuations. While large firms may experience longer inventory holding periods, smaller companies prioritize rapid inventory turnover to maintain cash flow efficiency.

The statistical analysis supports these findings, with the procurement cost model explaining 22.6% of the variation in costs based on crude oil price volatility, GDP growth, and company size. While other factors such as supplier negotiations, trade policies, and market demand may also influence procurement expenses, the significant role of oil price volatility cannot be ignored. Similarly, the inventory turnover model explains 9.7% of the variation in inventory management decisions, reinforcing that crude oil price fluctuations are an important determinant of stocking behaviour. The descriptive and explanatory analyses confirm that crude oil price volatility plays a critical role in shaping procurement and inventory strategies. As oil prices fluctuate, procurement costs tend to rise, forcing firms to adopt risk mitigation techniques such as supplier diversification and financial hedging. Simultaneously, inventory turnover decreases as firms hold onto stock longer to counter price uncertainty, requiring optimized inventory management practices. Larger firms bear higher procurement costs but benefit from bulk purchasing power, while smaller firms rely on agility to navigate oil price fluctuations. To enhance resilience, businesses must integrate predictive analytics, strategic sourcing models, and flexible inventory systems to optimize costs and maintain supply chain stability in volatile market conditions.

5. DISCUSSION

The findings of this study provide strong evidence that crude oil price volatility significantly influences procurement costs and inventory turnover, shaping strategic decision-making in supply chain management. The results demonstrate that fluctuations in crude oil prices are not just macroeconomic indicators but direct cost determinants that businesses must actively monitor and manage. These findings align with prior research that highlights the impact of oil price fluctuations on transportation costs, raw material procurement, and inventory stocking strategies, emphasizing the importance of risk mitigation in supply chain operations. Several past studies have established a direct relationship between crude oil price volatility and procurement costs. Prodromou and Demirer, (2022) argued that oil price shocks trigger cost escalations across global supply chains, affecting procurement budgets and financial planning. Similarly, Friedhoff et al., (2023) demonstrated that industries highly dependent on crude oil experience amplified cost pressures during periods of high price volatility. The present study builds on these insights by quantifying this relationship, showing that for every unit increase in crude oil price volatility, procurement costs rise by approximately $3.96 million. This reinforces the findings of Laing et al., (2022), who suggested that firms exposed to oil price risks must develop proactive cost control mechanisms to mitigate financial strain.

The study also establishes a negative relationship between crude oil price volatility and inventory turnover, indicating that as oil price fluctuations increase, firms hold onto inventory longer to hedge against cost uncertainty. This aligns with Chang et al., (2021), who noted that firms experiencing procurement cost variability tend to build buffer inventory, even at the cost of lower turnover rates. Wong and Zhang, (2023) further emphasized that supply chain managers prioritize inventory stability over efficiency when faced with external cost risks, a trend observed in industries reliant on crude oil-based inputs. The findings of this study confirm that companies strategically adjust their inventory cycles based on oil price conditions, adopting stockpiling approaches to avoid procurement cost surges. A key contribution of this study is its examination of procurement and inventory behaviour across firms of different sizes. The results suggest that larger firms experience higher procurement costs but benefit from economies of scale, whereas smaller firms maintain higher agility in adjusting sourcing strategies. This finding is in line with the work of Ferriani and Veronese, (2021), who argued that large firms prioritize bulk procurement to lock in stable pricing, whereas smaller firms leverage flexibility to minimize cost fluctuations. Safari et al., (2023) also highlighted that firm size influences exposure to supply chain risks, with large firms relying on long-term hedging mechanisms and smaller firms focusing on short-term adaptability. The present study extends these insights by providing quantitative validation of these firm-level differences in procurement and inventory behaviour.

Beyond procurement and inventory decisions, the findings also highlight the broader economic implications of oil price volatility on business operations. Aladwani, (2025) suggested that fluctuations in crude oil prices create inflationary pressures, impacting overall cost structures across industries. The present

study confirms that procurement costs are highly sensitive to crude oil price changes, reinforcing the argument that firms must incorporate macroeconomic indicators into their procurement planning. Additionally, prior research by Alzate-Ortega et al., (2024) indicated that oil price volatility has a more pronounced impact on businesses in emerging markets due to weaker supply chain resilience. The results of this study support this claim, suggesting that firms in oil-dependent economies must enhance risk management frameworks to mitigate crude oil-related supply chain disruptions.

5.1. Author's Perspective

From the author's perspective, the study's findings underscore the urgent need for businesses to transition toward data-driven procurement and inventory management strategies. The strong correlation between crude oil price volatility and procurement costs suggests that firms cannot afford to adopt reactive procurement approaches; instead, they must implement proactive risk assessment models. This includes integrating predictive analytics, machine learning models, and AI-driven cost forecasting tools into procurement planning to anticipate oil price changes and adjust sourcing decisions accordingly. Furthermore, supply chain digitization and automation can provide firms with real-time visibility into cost fluctuations, enabling more dynamic decision-making. Another key takeaway is the importance of developing hybrid inventory strategies. The study shows that businesses tend to stockpile inventory in response to crude oil price fluctuations, which, while ensuring supply security, also increases holding costs and working capital constraints. The author believes that companies must strike a balance between just-in-time (JIT) inventory management and strategic buffering, using AI-powered demand forecasting tools to optimize inventory levels in response to expected oil price changes. This shift from static to adaptive inventory policies will allow firms to navigate cost uncertainties more efficiently while maintaining financial flexibility.

Additionally, the study highlights the need for customized procurement strategies based on firm size. Larger firms benefit from long-term supplier contracts and economies of scale, whereas smaller firms rely on flexibility and responsiveness. The author suggests that large corporations should strengthen supplier diversification strategies, while smaller firms should explore agile procurement models to maintain cost competitiveness.

5.2. Future Research Directions

While this study provides valuable insights, several areas warrant further exploration. One key limitation is the lack of industry-specific segmentation in the analysis. Procurement cost structures differ significantly across industries such as manufacturing, energy, and logistics, and future research should examine how oil price volatility uniquely affects procurement decisions within specific sectors. An industry-focused approach would provide tailored risk mitigation strategies for businesses operating in different supply chain environments.

Another area for future research is the influence of geopolitical and regulatory factors on procurement and inventory decisions. While the study primarily focuses on crude oil price volatility, geopolitical instability, trade policies, and currency fluctuations also play a crucial role in procurement cost variations. Future studies could incorporate geopolitical risk indices and trade policy effects into econometric models to develop a more comprehensive understanding of external cost drivers. Moreover, advancements in machine learning and AI-driven supply chain optimization present opportunities for further research. Predictive analytics can enhance oil price forecasting, helping firms make real-time procurement adjustments. Future studies should investigate the effectiveness of AI-driven decision-making tools in minimizing procurement cost variability and optimizing inventory turnover during periods of crude oil price volatility.

Lastly, sustainability and alternative energy sources are becoming increasingly relevant in supply chain management. With firms looking to reduce dependency on crude oil, future research could explore how transitioning to renewable energy sources influences procurement costs and supply chain resilience. Investigating the economic impact of electric vehicle adoption, green logistics, and carbon-neutral procurement strategies could provide new insights into how firms can mitigate oil price risks in the long run.

6. CONCLUSION

This study provides empirical evidence that crude oil price volatility significantly impacts procurement costs and inventory turnover, emphasizing the need for proactive risk management in supply chain operations. The findings confirm that as crude oil price fluctuations increase, procurement costs rise, requiring firms to adopt supplier diversification, financial hedging, and predictive analytics to stabilize expenses. Additionally, inventory turnover decreases during periods of high oil price volatility, as businesses tend to stockpile inventory to hedge against procurement cost spikes, reinforcing the importance of optimized inventory management strategies. The study also highlights firm size as a determinant of procurement behaviour, where larger firms experience higher procurement costs due to bulk purchasing, while smaller firms rely on agility for cost adjustments. These insights align with prior research, reinforcing the need for data-driven procurement planning and dynamic inventory strategies to navigate oil price uncertainties efficiently.

Moving forward, businesses should leverage AI-driven forecasting tools, adaptive sourcing models, and strategic inventory buffering to mitigate the financial risks associated with crude oil price fluctuations. Future research should explore industry-specific procurement trends, geopolitical influences, and sustainability-driven supply chain transitions, providing deeper insights into long-term cost stability strategies in an increasingly volatile global market.

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