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Impact of Oil Price Uncertainty on Capital Structure Choice by Petroleum Companies

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Abstract:

Purpose: *The article examines the interaction between oil market uncertainty and the capital structure of large oil-producing companies. The research aims to establish whether oil companies adjust their capital structure in response to oil price volatility and uncertainty.*
Design/Methodology/Approach: *The study is based on historical financial data (debt/equity ratio; stock prices) for a sample of oil-producing companies listed on the NYSE over 2007-2022 to analyse their capital structure choices in response to oil price uncertainty measured by implied volatility (Oil VIX index) and realized volatility (WTI oil prices changes). Employed econometric methods include descriptive statistics, Pearson correlation, VAR Impulse response function, Granger causality, and GARCH model. Based on the literature review and historical data, the study uses an empirical approach to investigate the association between company debt and equity mix and oil price volatility and uncertainty.*
Findings: *The research demonstrates that fluctuations in market oil prices influence the capital structure of oil companies. Elevated oil price uncertainty, measured by the difference between the implied and realized oil price volatility (i.e., shocks) prompts oil companies to adjust their capital structure. According to the impulse response function, the oil price shocks exert a statistically significant short-term impact on the modifications in the capital structure of the sample oil companies. In general, companies tend to prefer liquid equity over sticky debt during higher oil price uncertainty. The Granger causality tests indicate a bidirectional relationship between oil price uncertainty and capital structure decisions. The results imply that, besides the advantages associated with the stability of sticky debt, it becomes more costly and risky during periods of oil market volatility.*
Practical Implications: *Studying large oil companies' capital structure is vital to those engaged in investment, policy-making, consumer advocacy, and public interest. The impact of uncertain oil prices on capital structure can serve as a guideline toward better financing decisions for financial managers in the oil sector. A higher proportion of equity needs to be maintained to avoid risks associated with debt in times of volatility.*
Originality/Value: *The paper contributes to the research on how world market oil price uncertainty impacts companies' capital structure decisions and proposes insights into finding optimal financing strategies for oil-producing companies facing volatile market conditions.*

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Up to now, similar studies focused on how oil price uncertainty affects companies in other sectors, with relatively low attention on companies from the oil sector.

Keywords: *Oil Price Uncertainty, Corporate Finance, Stock Market, Debt and equity mix.*

JEL Classification: *G30, G32, F00.*

Paper type*: Research article.*

1. Introduction

In the dynamic, often volatile world of oil production, many financial challenges affect the capital-structure decisions for companies. Capital structure is the mix of debt and equity financing, an essential ingredient of corporate finance that impacts risk and return. The article analyses the impact of oil price uncertainty (OPU) on the capital structure in an oil-producing companies by looking at the trade-off between “sticky debt” and a corresponding “liquid equity”.

Given the nature of oil price volatility, one can never take anything for sure concerning the price of oil, shifting gears from geopolitical events to simple market speculation. It exposes significant risks for oil-producing companies in managing their capital structure to retain financial stability and flexibility.

The nature of oil companies is distinct from that of non-oil companies, as evidenced by the experiences of firms confronted with unexpected challenges. The impact of oil price shocks on oil companies is more detrimental to their liquidity and cash flow positions than it is to non-oil firms. According to existing literature, severe oil price shocks and global recessions, which drive down oil prices, represent significant liquidity and cash flow challenges for oil firms (Narayan and Nasiri, 2020; Teti *et al.*, 2020).

In contrast with liquid equity, which is associated with greater flexibility due to the capacity to adapt to market fluctuations, sticky debt denotes long-term and less flexible debt commitments. It is of great consequence to firms engaged in an optimal capital structure search amid uncertainty to understand how oil price uncertainty affects the preference for these financing options.

This paper aims to address the following key research question: What impact does uncertainty around oil prices have on the capital structure decisions made by oil producers? Its answering is essential for several reasons. Principally, it offers insight into how firms adjust their financing strategies in response to exogenous economic shocks. It also offers practical insights on how financial managers in the oil industry can make informed decisions regarding capital structure amid fluctuating oil prices. The research is original since it examines the relationship between oil price uncertainty and capital structure decisions in oil companies, a topic largely overlooked in existing empirical literature.

2. Literature Review

The impact of oil price uncertainty (OPU) on the firms' decisions to change their capital structure, defined as the relationship between a company's equity and debt, has not received sufficient attention in the academic literature. Nevertheless, the exact literature on oil price uncertainty and capital structure formation consists of a multi-faceted view about setting financial strategies under volatile oil prices. In his 1999 paper, Andrew Abel presents a seminal understanding of how risk factors, like those associated with volatile oil prices, can influence capital structure decisions (Abel, 1999).

By analysing the risk premium (the expected excess rate of return on a risky asset relative to the rate of return on a riskless asset of the same maturity) and the term premium (the excess of the expected one-period rate of return on an n-period asset over the expected one-period rate of return on a one-period asset with the same value), he gave insight into the underlying factors influencing the choice of capital structure. His general equilibrium model illustrates how firms may adjust their financing patterns in response to perceived risks, thus providing a foundation for understanding the broader implications of oil price uncertainty on capital management.

As previously stated, a company's capital structure or leverage can be defined as the relative proportions of debt (D) and equity (E). The company raises capital to finance its assets, which are expected to generate cash flow. A company may raise capital in two ways: through the issuance of equity or the incurrence of debt. One of the literature's most well-known theories on corporate financing decisions is the pecking order theory.

The theory was proposed by Gordon Donaldson, who observed that firms tend to rely on internal capital as a financing source. It was subsequently expanded upon by Steward Myers and Nicholas Majluf. The theory generally explains several aspects of corporate financing behaviour, including the tendency to rely on internal sources of funds and favour debt over equity when external financing is required (Donaldson, 1961; Myers and Majluf, 1984). From our research perspective, it is worth noting that the pecking order theory does not pose an optimal debt ratio (Myers, 1984).

The trade-off theory is the second prominent theory that can explain the choice of debt-equity ratio (D/E). This theory suggests that the choice of capital structure is related to the balance of costs and benefits of debt versus equity financing (Myers, 1984). It also posits that the expansion of debt financing should be contingent upon the debt tax shield derived from the interest deduction utilised in calculating pre-tax profit. It is reasonable to assume that companies with secure, tangible assets and a significant amount of taxable income to protect would be expected to have higher target debt ratios.

Conversely, companies with low profits and risky tangible assets should rely primarily on equity financing. The oil and gas industry can be characterized as a capital-intensive sector. This sector requires substantial fixed assets for operational purposes, which can be leveraged as collateral for debt.

The two fundamental capital structure theories, the pecking order theory and the trade-off theory were subjected to empirical testing on a sample of about 60 large Russian public and private companies operating in nine different industries, including the oil and gas industry but excluding the financial sector (Ivashkovskaya and Solntseva, 2007).

The analysis was unable to reject either the pecking order or trade-off theory. The internal financing deficit was an essential factor in modelling the capital structure, but not the only one. When the firms' sample was divided into those with a high debt ratio (above the average) and those with a low debt ratio, the pecking order preference for companies with a high debt ratio became clear.

The results referring to companies according to ownership were of particular significance. It was evident that the dominance of the pecking order was prevalent in companies under government control. Conversely, for other companies, a slight superiority of the trade-off theory was discernible. In the case of private Russian companies, however, only the trade-off theory accounted for the observed capital structure choices.

The results for India and China also show that different industries perfectly align with the pecking order during deficiency. In the case of China, however, the oil, gas and electricity industries follow a relatively weak pecking order (Bhama *et al*., 2017). Another study, which investigated the determinants of the capital structure of the 22 listed oil and gas companies in the Gulf Council Countries over ten years (2010-2019), concluded that these companies aligned with the trade-off theory or pecking order theory.

The results demonstrate a markedly positive correlation between the size of the company and the debt-to-equity ratio. This suggests that firms tend to utilise leverage to a greater extent when they possess substantial fixed assets that can be used as collateral (Ahmed and Sabah, 2021).

The third contribution to the theory of capital structure is Modigliani and Miller's theory hypothesising that the cost of capital of levered equity increases with the firm’s market value debt-equity ratio (Modigliani and Miller, 1958). Their study concerns, among others, oil-producing companies, where price volatility in the oil sector can be very sharp. Their theory of capital structure posits that firms may derive a tax shield from augmented indebtedness, thereby establishing a positive correlation between the debt-to-equity ratio and profitability.

The researchers identified a positive correlation between leverage and rate of return. The Modigliani-Miller and trade-off theories diverge in their assessment of the optimal debt ratio for firms. The former posits that firms should assume as much debt as possible, whereas the latter advocates for a more moderate approach and justifies using lower debt ratios.

A substantial body of research has been undertaken at both the theoretical and empirical levels to identify the factors influencing capital structure; however, many conflicting findings have emerged from previous research studies. Drawing from the three above theories, Swedish scholars (Aberg and Andersson, 2022) analysed the relationship between firm performance and capital structure from an investor’s perspective by basing the analysis on stock returns in Swedish companies.

Specifically, they examined how the stock market responded when companies issued more debt. Their empirical study indicates that higher leverage is likely to increase returns but also raises risks.

The investigation of a sample of publicly listed corporations based in Saudi Arabia, the United Arab Emirates, and Qatar for a period spanning from 2005 up to the end of 2014 revealed that the firm's size, profitability, tangibility, age, and tendency to pay dividends were significant determinants of conventional leverage (El-Khatib, 2017). It should be noted that this study does not include oil and gas companies.

The decision-making process regarding capital structure is of paramount importance for any company, as it exerts a profound impact on the overall value of the enterprise and the weighted cost of capital (WACC), which is constituted by the costs of debt and equity.

The capital structure directly impacts the value of the shares held by shareholders. The company management team's responsibility is to balance risk and return to maximise shareholder value by creating the optimal capital structure. According to (Diana *et al.*, 2016), the optimal capital structure maximises the market prices of shares by balancing risks and returns.

The global economic and financial crisis of 2007-2008 prompted energy sector companies to diversify their finance sources (Rossi *et al*., 2019). Furthermore, with a record low level of oil prices in 2015, oil companies that borrowed money to invest in infrastructure against an assumed high oil price a barrel struggled to service the loans and were forced to look for debt restructuring (Holland, 2016).

Oil companies may, therefore, feel pressured to balance the gains from higher leverage with the heightened risk brought on by crude oil price volatility. The behaviour of oil price uncertainty in stock markets was empirically documented in the literature. The reviewed studies indicate that oil price fluctuations influence stock market performance (Ågren, 2006; Guesmi *et al.,* 2016; Cheema and Scrimgeour, 2019; Liu *et al.*, 2023).

For example, during the financial crisis and the COVID-19 pandemic, gold and crude oil have emerged as the two commodities with the most significant impact on global stock markets. It is thus incumbent upon oil-producing companies to modify their financial decisions to align them with the inherent risks associated with fluctuations in oil prices. They may need to implement more sophisticated risk management strategies to mitigate the adverse effects of oil price volatility on their capital structure.

Indian researchers (Akhtar and Sushil, 2018) discuss the implications of this market uncertainty on financial strategies in the Indian oil industry, comprising 15 public (government-owned) and private companies involved in the upstream business of oil and gas exploration and production. Their empirical study has revealed the role of adaptive performance management systems in sailing through volatile market conditions.

Their findings suggest that oil-producing companies must demonstrate agility in their capital structure decisions and pursue a deliberate strategy of modifying their financing approach in response to shifts in the market environment. Russian scholar (Balashova, 2021) examines the relationship between oil price volatility and total factor productivity growth for the global economy (an aggregate of 123 countries), the European Union (28 members), and the OECD over the 1980-2018 period.

The findings indicate a robust negative Granger causality from oil price volatility to the cyclical component of TFP growth, especially in periods characterised by substantial fluctuations in oil prices. This phenomenon can be explained by the intuitive assumption that the inherent uncertainty of oil prices causes investors to adopt a risk-averse investment strategy.

The study findings suggest that uncertainty regarding oil prices may indirectly influence capital structure decisions due to the potential for a decline in productivity, which in turn necessitates adjustments to financial strategies.

Another evidence that OPU has important implications for corporate financing policy is provided by research conducted on a sample of US firms, including those operating in the oil industry, from 1985 to 2019 (Hasan *et al*., 2022). The authors attempt to determine how OPU can lead to an optimal corporate debt maturity structure. The results suggest that companies change the maturity profile of their debt in response to evolving oil price conditions, tending to shorten maturities (up to five years) to omit the risk inherent in long-term maturities.

The research shows that oil price uncertainty affects capital structure decisions related to debt management. Some scholars (He *et al*., 2022) extended this analysis by examining the link between the oil price uncertainty and risk-return trade-off in stock markets of the major oil-importing and exporting countries. Their empirical study indicates that OPU changes impact firms depending on their oil exposure.

On average, stock markets had significantly positive risk-return relations when the crude oil volatility index (OVX) changes were negative. In contrast, the positive relation was undermined, becoming inverse when the OVX changes were positive in both oil importers and exporters. In addition, the OVX shock (the global financial crisis in 2008) significantly negatively impacted the risk-return relation in oil-importing and oil-exporting countries. This study's findings contribute to understanding how oil price volatility might affect firms' adjustments in capital structure in different contexts of markets.

The other line of research enriches the existing literature by exploring the effect of uncertainty on corporate investment (Elder and Serletis, 2010; Henry, 1974; Phan *et al.,* 2019). Phan and co-authors examined the impact of global crude oil price uncertainty on firm-level investment, applying a comprehensive dataset of more than 33,000 firms from 54 countries from 1984 to 2015. The research indicates that OPU hurts business investment spending.

This effect was more pronounced in oil-producing countries and oil industries than in oil-consuming countries. The effect was weaker during the global financial crisis and stronger during market volatility. Generally, the impact of oil price uncertainty on investments depended on the market and stock characteristics of the firms. According to (Elder and Serletis, 2010), uncertainty about the future return on the investment induces optimizing agents to postpone investment as long as the expected value of additional information exceeds the expected short-run return to the current investment. As uncertainty is reduced, firms tend to become more inclined to commit investible resources.

In conclusion, examining existing literature indicates that oil price uncertainty directly or indirectly influences oil-producing firms' capital structure decisions. The findings of these studies consistently highlight the importance of effective risk management strategies, the impact of oil price fluctuations on debt maturity choice and investment decisions, and the indirect effects of price changes on factor productivity and, subsequently, economic growth.

The results contribute to a deeper understanding of how external economic factors influence the capital structure choices of firms. Furthermore, they offer practical insights for financial managers in the oil industry. In light of the inherent uncertainty of oil prices, it is evident that adaptive and dynamic capital structures are necessary: firms must navigate the complex nature of finance and changing volatility.

3. Research Methods and Sources

This section begins with a more detailed explanation of the first indicator used in the empirical study, capital structure, as expressed by the debt-equity ratio (D/E). It represents a pivotal financial metric whereby a company's total liabilities are compared to its shareholder equity (total equity value). It measures the extent to which a firm finances its operations using debt instruments compared to wholly-owned funds.

This ratio offers insights into the company's solvency, financial leverage, and risk profile. A higher D/E ratio suggests the company relies more on borrowed capital, indicating a greater investor risk. On the other hand, a lower D/E ratio indicates less reliance on borrowed funds and may be seen as less risky. Table 1 presents a series of detailed considerations when analysing a company's capital structure.

Table 1. *Dimensions of capital structure (the debt to equity ratio)*

Dimensions	Description
Leverage Impact	A high D/E indicates a company's aggressive financing of its growth through debt. This can result in volatile earnings due to the additional interest expense.
Investor Consideration	The D/E ratio provides equity investors insight into the extent to which a company has sufficient equity to cover its debts in the event of a downturn. They prefer a moderate D/E ratio that indicates a stable financial position.
Industry Standards	The acceptable D/E ratio depends on the industry. For instance, capital-intensive industries like oil and gas companies might have higher standards for D/E ratios, while technology or service firms might typically have lower ratios.
Economic Conditions	During periods of low interest rates, companies may increase their debt to leverage their growth due to the cheaper borrowing costs. However, this strategy may prove ineffective if economic conditions change and interest rates rise.
Bankruptcy Risk	A very high D/E ratio may precipitate bankruptcy in unfavourable conditions, as the company may encounter difficulties servicing its debt.
Tax Shields	Debt can be a tax shield as interest payments are eligible for tax deductions. This can render debt a more attractive form of financing up to a certain point.
Return on Equity (ROE)	While debt can enhance ROE due to the leverage effect, it simultaneously elevates the risk. An optimal D/E ratio maximises ROE while minimising risk.

Source: *Own compilation based on (FasterCapital, 2024).*

The other characteristic considered is oil price uncertainty (OPU). The study used two variables to assess the OPU. The first is the Oil Volatility Index (OVX), called the Cboe Crude Oil ETF Volatility Index. This statistical measure reflects the market's expectation of 30-day volatility for US crude oil. Initially published in 2007, the OVX has since become a valuable tool for traders to track and analyse the volatility of future oil prices (Thaxton, 2023).

The second variable is WTI (West Texas Intermediate) crude oil prices. The OVX, or implied volatility, was confronted with the realised volatility of spot WTI oil prices to estimate the OPU via the variance swap approach. The initial data were downloaded from LSEG Data and Analytics.

The empirical analysis was based on a panel dataset comprising major oil producers in various global regions, listed on the New York Stock Exchange (NYSE) and spanning from 10 May 2007 to 5 September 2022. This period encompasses multiple economic and market conditions (e.g., the Great Recession during the global financial crisis and the COVID-19 pandemic). It thoroughly allows us to explain how OPU affects capital structure decisions.

The companies under investigation are the nine oldest oil producers listed on the NYSE: Chevron, Exxon Mobil, Texas Pacific Land, Southwest Energy, Occidental Petroleum, Murphy Oil, EQT Corporation, Earthstone Energy, and ConocoPhillips. This selection was based on the recommendations of analysts at Saxo Bank, who predicted that the shares of these companies were undervalued. Closing prices for the shares of these oil companies have been used.

The empirical part is devoted to assessing the effects of OPU on changes in the capital structure (D/E ratio level and the variability of debt/equity ratio adjusted rates of share returns). The methods employed in the study include:

(1) the Generalized Autoregressive Conditional Heteroskedasticity (GARCH 1.1.) model to capture realized daily oil price volatility based on historical data; historical volatility is estimated based on the standard deviations observed in a sample;

(2) Pearson correlation analysis;

(3) the Impulse Response Analysis (IRA) of a Vector Autoregressive (VAR) model to identify the effects of OPU on capital structure indicator;

(4) AR(1)-GARCH(1,1) approach to capture volatility spillover between the capital structure and oil price uncertainty;

(5) the causality analysis using the panel Granger causality tests which yield results indicating whether OPU can be employed to forecast the capital structure variable. This approach offers valuable insight, enabling the assessment of the predictive

power of lagged values within panel data and pointing towards plausible causal relationships from oil price fluctuations to capital structure adjustments.

The research employed the rugarch package in R software (the R Project for Statistical Computing).

4. Results and Discussion

Descriptive Statistics:

Table 2 presents the descriptive statistics for a sample of oil companies' valuation expressed as the closing spot stock market price multiplied by the debt-to-equity ratio, from 10 May 2007 to 5 September 2022. This measure reflects the market value per share adjusted for the D/E ratio. It is important to note that enterprise value (EV) measures its total value encompassing not only its market capitalization but also incorporates short-term and long-term debt (in plus), in addition to any cash or cash equivalents reflected on the company's balance sheet (in minus).

This method is often used to evaluate a company as a more comprehensive alternative to market capitalization. Capital-intensive industries, such as the oil industry, typically carry significant amounts of debt, which is employed to stimulate growth by acquiring plants and equipment. On the other hand, the fundamental determinants of the value of oil and gas companies are their reserves, production levels, and commodity prices at the time of valuation. These factors potentially impact the company's equity value (Bhaskaran and Sukumaran, 2016).

A company's stock price may be more susceptible to market fluctuations if it exhibits a high D/E ratio. A high level of the D/E can exert an influence on the decline in demand for shares in the market, which will, in turn, result in a reduction in the price of these shares.

In the “maximum” row of Table 2, Texas Pacific Land exhibited the highest adjusted stock price value of approximately 1888 USD, while EarthStone Energy demonstrated the lowest value of about 38 USD. In the "minimum" row, Earthstone exhibited a price of approximately 2 USD, while Texas Pacific Land exhibited a price of roughly 16.5 USD. However, the highest recorded minimum value among sampled companies was in Chevron, at approximately 62.9 USD.

The descriptive statistics demonstrate considerable variability in the data across the companies in question. For example, the maximum value observed for Texas Pacific Land is considerably higher than that of the other firms, suggesting the presence of outliers or exceptional cases.

Similarly, most standard deviations (SD) are considerable for a given firm, indicating that the financial ratios exhibited high variability. This suggests that the effects of uncertainty on oil prices are significant.

An examination of the kurtosis row (Returns or first differences) reveals that all the values are derived from a leptokurtic distribution. The highest kurtosis is observed in Southwest Energy, with a rounded value of 248, followed by Occidental Petroleum with a value of 137. In contrast, Earthstone Energy exhibits the lowest kurtosis (5.95). These values suggest that Southwest Energy and Occidental Petroleum were the most sensitive to change, while Earthstone Energy and EQT were the least.

For investors, a high kurtosis of the return distribution curve means that there have been many price fluctuations (positive or negative) away from the average returns of the investment in the past. Therefore, an investor may experience extreme price fluctuations in an investment with a high kurtosis.

Table 2. *Summary statistics for oil companies' valuation per share (D/E × stock price, USD)*

Statistics	Chevron	Exxon	Texas Pacific Land	Southwest Energy	Occidental Petroleum	Murphy Oil	EQT	Earthstone Energy	Conoco Phillips
The levels over a period spanning from 10/05/2007 to 5/09/2022									
Mean	122.7	91.8	350.6	42.3	103.5	54.6	48.5	14.2	83.1
Minimum	62.9	45.0	16.5	2.7	43.0	8.0	7.6	2.1	34.3
Maximum	222.0	134.3	1888.0	122.1	286.2	101.4	98.8	38.1	176.6
1. Quartile	102.2	81.4	45.5	18.2	88.2	43.1	33.9	9.8	71.3
3. Quartile	140.2	101.8	554.9	57.4	110.5	67.8	60.2	17.8	95.4
Median	126.1	93.8	141.5	44.7	99.4	52.8	48.0	13.3	81.9
SD	27.0	15.4	435.0	26.4	34.6	18.0	18.7	6.5	21.2
Skewness	0.31	-0.46	1.58	0.55	2.25	0.01	0.28	0.86	0.70
Kurtosis	0.53	-0.09	1.62	-0.09	6.92	-0.43	-0.31	0.96	1.34
Returns or first differences									
Maximum	0.205	0.159	0.262	1.468	0.684	0.233	0.317	0.304	0.225
1.Quartile	-0.008	-0.008	-0.011	-0.018	-0.011	-0.014	-0.013	-0.019	-0.010
3.Quartile	0.009	0.008	0.013	0.018	0.011	0.015	0.014	0.018	0.011
Mean	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Median	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SD	0.019	0.018	0.027	0.049	0.033	0.032	0.028	0.043	0.023
Skewness	-0.453	0.021	0.008	5.583	0.327	-1.216	0.226	0.379	-0.357
Kurtosis	22.17	11.31	10.79	247.80	137.30	26.37	9.07	5.95	14.44

Notes: *Returns or first differences are adequate transformations for the predictor variables. Using the first difference, we can get stationary series (series integrated of order 1) from non-stationary series.*
Source: *Authors' calculations based on LSEG Data and Analytics data.*

Correlation Analysis:
The current analysis employed the rolling Pearson's correlation coefficients (R) to test the relationship between the OPU and capital structure indicator (based on Table 2). The objective is to examine changes rather than levels of these indicators to

ensure stationarity. Positive correlations indicate that higher oil price volatility goes with increased leverage ratios, suggesting that firms may rely more on debt financing in a period of high uncertainty to sustain liquidity.

The results of our research demonstrate a notable shift in the correlation between oil companies' capital structure ratios (D/E × stock price) and oil price uncertainty over time. Notably, the correlation coefficients may exhibit considerable variation during periods of elevated market volatility, compared to those observed during relatively tranquil market conditions (Loretan and English, 2000).

According to our results, the correlations between capital structure changes and oil price uncertainty changes were either weakly positive (with R generally up to 0.2 for each company) or moderately negative (R up to -0.4 respectively) with oil price uncertainty changes. At specific points in time, the coefficients demonstrated the most robust positive correlation with the OPU (with R reaching 0.4 for EQT, Earthstone Energy, and ConocoPhillips) or the most pronounced negative correlation (with R = -0.7 for Texas, Murphy, and ConocoPhillips).

To conclude, the sampled companies modified their capital structure in response to fluctuations in oil prices, with a range of correlation coefficients, including zero, as well as very weak positive or strong negative correlations. These observations generally suggest that the relationship between OPU and leverage is sensitive to fluctuations in oil market conditions. The varying correlation levels among companies suggest their differing strategies and sensitivities to fluctuations in oil prices.

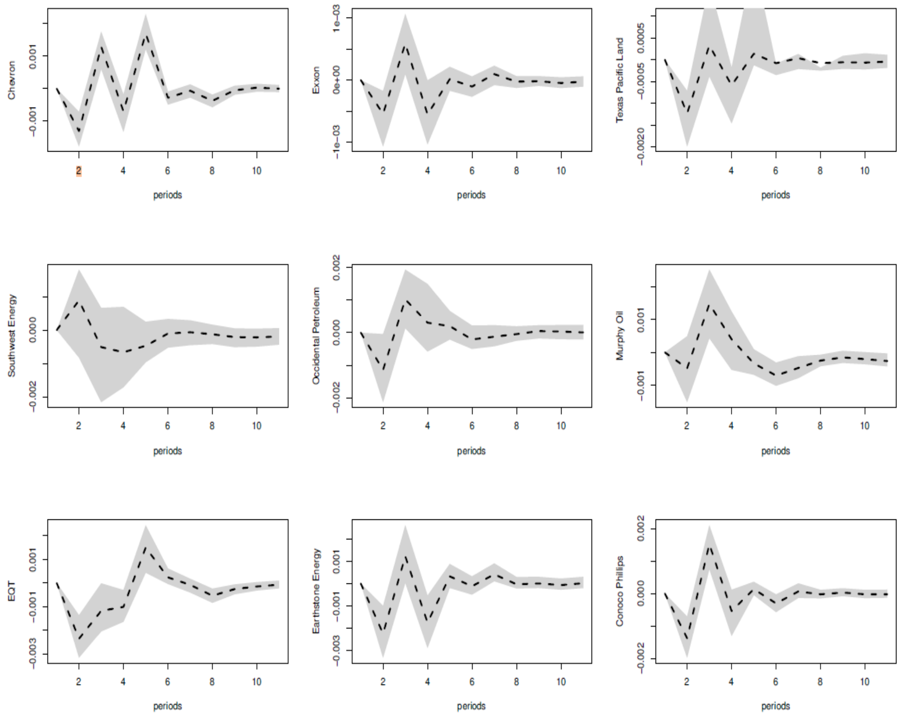
4.1 Capital Structure Reaction to Economic Frictions – VAR Impulse Response Function Results

Since the publication of the seminal work by Christopher Sims (Sims, 1980), vector autoregressive (VAR) models have become a standard tool in applied economic analysis, including the effects of oil price shocks (Kilian, 2009). In this section, the study employs the bivariate vector autoregression (VAR) model with lag length selection based on the information criterion to ascertain the dynamic relationship between variables (Granger, 1969; Koop *et al.*, 1996).

In this case, the focus is on the relationship between capital structure and the OPU. The VAR approach is useful for answering questions about how a shock affects things in a certain period. It helps trace through a system taken by shocks in propagation, along with feedback loops between variables. In practice, the principal applications of the VAR are impulse response analysis, variance decomposition, and Granger causality tests.

The results of the impulse response function (IRF) are shown in Figure 1. The IRF gives the *j*th-period response when the system is shocked by a one-standard-deviation shock. In the case of our research, IRF expresses how a change in capital structure indicator (D/E × stock price) responds to a sudden surge in oil price variability.

Figure 1*. Responses of the Capital structure to oil price uncertainty (shocks)*



Notes*: The vertical axis (y-axis) shows the reaction of a unit change in the response variable (capital structure) given a unit (one standard deviation) one-time positive shock to x (OPU), ceteris paribus. The horizontal axis represents the impact lag time (from 1 to 12). The inner solid line signifies the effective response. The shadow area represents the estimates for 95% confidence intervals (bands).*

Source: *Authors' calculations based on transformed data in Table 2.*

The simulation of how the capital structure reacts to an unanticipated increase in the OPU (the difference between the expected and realized oil price fluctuations) over the next 12 periods suggests that the oil price shocks had a statistically significant impact on the changes in the capital structure of the sample oil companies (Figure 1).

This is the same result as previously identified in the Pearson correlation analysis. For example, the considerable price uncertainty shocks from the oil sector led to an increase in the leverage ratio of most companies.

Figure 1 demonstrates that response variables for all companies fluctuate around 0 without displaying a noticeable tendency. Moreover, there are discernible discrepancies in the extent of variation observed in the variables over different time intervals. After a sudden shock, the capital structure reverted to its pre-event state.

The majority of companies exhibited comparable behaviour, except Southwest Energy. The adjustment process was analogous. Consequently, the impact of sudden, significant fluctuations in oil prices on the capital structure of oil producers was not fixed or long-term.

Empirical evidence suggests that companies alter their capital structures over time. The effect of unexpected shocks on capital structure is mostly short-term, occurring within the first year, in line with the uncertainty shocks concept (Bloom, 2009). The persistent effect of shocks on leverage is more likely due to capital adjustment costs than indifference toward capital structure (Leary and Roberts, 2005).

4.2 The Capital Structure Variability and Oil Price Uncertainty – Volatility-Induced Adjustment Processes

To provide supplementary information regarding the effects of changes in the OPU on changes in capital structure (expressed by share returns adjusted for debt/equity ratio), this research employs an AR(1)-GARCH(1,1) model with a conditional normal distribution. This is done to capture the nature of capital structure volatility, wherein oil price uncertainty serves as the exogenous or external variable.

An AR(1)-GARCH(1,1) structure effectively explains the residual variation over time and is commonly used to describe market series during normal regimes or non-crash periods (Gazola *et al.*, 2008). Its application represents a potential solution to the challenges posed by the high volatility and heteroskedastic variance often encountered in financial and economic time series data.

The oil price shocks are estimated as the residuals of an AR(1) process. The AR(1)-GARCH(1,1) model results for nine oil companies have been shown in Table 3.

The alpha, beta, and omega parameters are essential to interpret GARCH model results. Omega (constant term) represents the long-run average variance of the time series. A higher omega denotes a higher baseline level of volatility. Alpha gauges the influence of past squared returns (or shocks) on present volatility, indicating the extent to which the current volatility can be attributed to recent shocks. A higher alpha value indicates that recent shocks exert a bigger impact on future volatility.

Beta, on the other hand, represents the impact of past conditional variances on current volatility and captures the persistence of volatility over time. A higher beta signifies that volatility is more persistent or that volatility shocks (i.e. innovations) have longer effects. The sum of alpha and beta parameters close to 1 indicates high volatility persistence.

Table 3. *AR(1)-GARCH (1,1) process results – estimated model parameters*

Parameter	Estimate	Std. Error	t-value	p-value	Estimate	Std. Error	t-value	p-value
	Chevron				Exxon			
mu	0.0004	0.0002	2.2	0.0249	0.0002	0.0001	3.9	0.0001
ar1	-0.0099	0.0167	-0.6	0.5529	-0.0216	0.0169	-1.3	0.1998
omega	0.0000	0.0000	1.1	0.2762	0.0000	0.0000	34.7	0.0000
alpha1	0.0659	0.0016	42.3	0.0000	0.0583	0.0013	44.7	0.0000
beta1	0.9201	0.0151	60.9	0.0000	0.9376	0.0023	406.1	0.0000
vxreg1	0.0000	0.0000	3.2	0.0014	0.0000	0.0000	35.5	0.0000
	Texas Pacific Land				Southwest Energy			
mu	0.0013	0.0003	3.9	0.0001	-0.0004	0.0000	-3649.7	0.0000
ar1	-0.0033	0.0184	-0.2	0.8574	0.0098	0.0000	3649.9	0.0000
omega	0.0000	0.0000	5.6	0.0000	0.0000	0.0000	1.0	0.3270
alpha1	0.1825	0.0182	10.1	0.0000	0.1005	0.0000	3624.5	0.0000
beta1	0.7875	0.0207	38.1	0.0000	0.9010	0.0002	5366.7	0.0000
vxreg1	0.0000	0.0000	0.0	1.0000	0.0000	0.0000	0.0	0.9629
	Occidental Petroleum				Murphy Oil			
mu	0.0005	0.0003	1.4	0.1743	0.0001	0.0004	0.4	0.7068
ar1	-0.0624	0.0183	-3.4	0.0007	-0.0017	0.0172	-0.1	0.9234
omega	0.0000	0.0000	1266.3	0.0000	0.0000	0.0000	5.5	0.0000
alpha1	0.1483	0.0002	849.1	0.0000	0.0823	0.0076	10.8	0.0000
beta1	0.8767	0.0016	547.1	0.0000	0.9160	0.0075	122.1	0.0000
vxreg1	0.0000	0.0000	2.7	0.0073	0.0000	0.0000	0.0	0.9971
	EQT				Earthstone Energy			
mu	0.0000	0.0004	0.0	0.9809	0.0001	0.0006	0.1	0.9230
ar1	-0.0061	0.0170	-0.4	0.7175	0.0014	0.0177	0.1	0.9370
omega	0.0000	0.0000	13.7	0.0000	0.0000	0.0000	5.2	0.0000
alpha1	0.0453	0.0037	12.2	0.0000	0.0689	0.0098	7.1	0.0000
beta1	0.9428	0.0042	224.0	0.0000	0.9127	0.0117	77.9	0.0000
vxreg1	0.0000	0.0000	0.0	0.9951	0.0000	0.0000	0.0	0.9999
	ConocoPhillips							
mu	0.0006	0.0000	11.8	0.0000				
ar1	-0.0439	0.0172	-2.6	0.0106				
omega	0.0000	0.0000	2.8	0.0051				
alpha1	0.0645	0.0056	11.5	0.0000				
beta1	0.9339	0.0056	166.7	0.0000				
vxreg1	0.0000	0.0000	9.1	0.0000				

Notes: *AR(1) – first-order autoregression, the value of the process at time t1 depends on the value of the process at t−1; mu – mean parameter; ar1 – AR(1) parameter; omega – variance intercept parameter; alpha1 – ARCH parameter; beta1 – GARCH parameter; vxreg1 – external regressor parameter.*

Source: *Authors' calculations based on Table 2.*

The estimated beta parameters for all companies are statistically significant and high, suggesting that capital structure volatility was persistent over time or, in other words, that past volatility played a role in current volatility.

Alpha parameter estimates are also statistically significant. Their values above 0.1 for Texas Pacific Land, Southwest Energy, and Occidental Petroleum suggest that past shocks influenced these companies' long-term average capital structure volatility more than the remaining companies.

The value of alpha 1 is the highest for Texas Pacific Land, indicating that the impact of a shock was the most significant in this company. Based on the values of beta 1, the duration of the shock was the longest for EQT, while it was the shortest for Texas Pacific Land.

As evidenced in Table 3, the estimated value of vxreg1 is zero for all companies and is not statistically significant for five of them. Nevertheless, this parameter representing the regression coefficient of the exogenous variable OPU in the conditional variance equation is statistically significant for Chevron, Exxon, Occidental Petroleum, and ConocoPhillips, suggesting that these oil companies can be more sensitive to changes in the volatility structure of the market oil prices.

Given that the estimated parameter vxreg1 is equal to zero, even if statistically significant, the effect of oil price uncertainty on the risk of investing in an oil-producing company is also zero.

Therefore, from an investor's standpoint, there is no additional risk when the capital structure is adjusted and the producer's profit is stable. It is important to note that there is a standard, ordinary risk of oil price fluctuations.

Nevertheless, it is not the case that any additional risk is involved when there is a discrepancy between investors' predictions or implied volatility and the realized volatility of oil prices.

4.3 Panel Causality Analysis

The VAR model permits the testing of Granger causality, a statistical hypothesis test employed to ascertain whether one time series can be used to predict another. It is worth noting that Granger causality does not imply true causality but rather indicates the predictive power of time series relationships (Rao, 2024).

This section applies the Granger causality test to determine the causal interrelation between the time series of the variability of the capital structure and OPU for the panel data. The results indicate that most of the investigated oil companies can exhibit a significant causal relationship in both directions, as illustrated in Table 4.

The Granger tests suggest that the OPU causes a change in capital structure as companies adjust it in response to past oil price uncertainties. Conversely, decisions regarding capital structure give rise to the OPU, thereby establishing a feedback loop whereby financial decisions exert an impact on market perceptions regarding oil price stability.

Table 4. *Results of the Granger causality test*

Company	Constant		Capital structure → Oil uncertainty		Oil uncertainty → Capital structure	
	Stat	p-value	Stat	p-value	Stat	p-value
Chevron	111.493	0.0000	7.144	0.0000	14.806	0.0000
Exxon	79.723	0.0000	4.068	0.0027	2.974	0.0182
Texas Pacific Land	49.509	0.0000	7.671	0.0000	2.657	0.0312
Southwest Energy	10.955	0.0009	0.872	0.4798	1.025	0.3925
Occidental Petroleum	112.974	0.0000	7.344	0.0000	2.288	0.0575
Murphy Oil	101.821	0.0000	5.047	0.0005	4.680	0.0009
EQT	3.831	0.0503	9.598	0.0000	11.406	0.0000
Earthstone Energy	15.737	0.0001	4.171	0.0022	5.184	0.0004
ConocoPhillips	100.540	0.0000	5.428	0.0002	8.002	0.0000

Source: *Authors' calculations based on Table 2.*

The authors also examined the impact of certain firm characteristics, particularly their size and asset tangibility on the response of their capital structure to the OPU. The evidence suggests that larger companies with high levels of tangible assets were less likely to change their capital structure decisions.

An illustrative case is that of Chevron, which maintains an extensive asset base and shows a comparatively slower response to oil price fluctuations than smaller or less asset-rich companies.

5. Conclusions

The findings of the research for nine major oil-producing companies over the 2007-2022 period indicate that uncertainty regarding market oil prices was a significant factor influencing their capital structure decisions. The impulse response functions and the Granger causality test confirmed the dynamic adjustment phenomenon.

The latter demonstrated the existence of complete bidirectional causality between the OPU and capital structure decisions. Therefore, these findings support the argument for incorporating oil price volatility into financial planning and decision-making processes within the oil industry.

The AR(1)-GARCH (1,1) model for capital structure changes volatility over time, incorporating OPU as an external variable indicates that oil price uncertainty does not cause additional investor risk resulting from the discrepancy between implied volatility and the realized volatility of oil prices. It would be erroneous to assume that there is no risk involved. Fluctuations in oil prices over time are an inherent and typical risk factor.

Our findings suggest that the relationship between oil price uncertainty and capital structure is crucial for corporate decision-making. Ignoring a firm's specific leverage levels and the risks related to fluctuating oil prices can lead to poor choices about the optimal capital structure.

Despite many successes in understanding the relationship between capital structure and oil price uncertainty, some research gaps still need to be addressed. In particular, subsectors of the oil industry and regional differences in oil price sensitivity are worth investigating.

Finally, the role of new financial instruments and risk management strategies can be investigated according to their impact on constructing/changing insights into oil price volatility and capital structure decisions.

The study has several limitations. The first relates to the data available and its quality. The study uses historical financial data, which may poorly reflect recent changes in market dynamics or new trends in oil price volatility.

Second, the scope of the data set covers only major oil-producing companies and excludes most of the smaller or non-traditional players in the oil market. The methodology has its limitations, which affect the analysis.

While the used panel dataset and a VAR model may appear robust, they cannot capture all the external factors that could influence capital structure decisions, such as geopolitical events or technological developments in oil-related activities. Future research could be improved by including more companies, small companies, or emerging companies in the oil market.

Other macroeconomic and industry-specific variables would go a step further in explaining the determinants of capital structure. Similarly, exploring alternative methodologies, such as machine learning techniques, could improve these findings. In other words, this research adds to the current literature on how oil price uncertainty affects capital structure decisions.

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