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The Ups and Downs of Oil Prices: Asymmetric Impacts of Oil Price Volatility on Corporate Environmental Responsibility

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The Ups and Downs of Oil Prices: Asymmetric Impacts of Oil Price Volatility on Corporate Environmental Responsibility

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Abstract: This paper examines the impact of crude oil price changes on corporate environmental responsibility among U.S. non-oil and gas producer firms from 2002 to 2020, focusing on the asymmetric effects of oil price volatility. We distinguish between volatility due to increases or decreases in oil prices and find that a one standard deviation increase in oil volatility from positive price changes leads to a 12.7% decrease in environmental score, while the same increase from negative changes results in only a 5.5% decrease. Financial constraints are identified as a potential channel through which oil price volatility influences environmental activities. Specifically, a one standard deviation increase in oil volatility from positive price changes leads to an 18% decrease in environmental score for firms with high financial constraints, compared to an 8% decrease for firms with low financial constraints. Our findings are robust to sector differences and a 2SLS model addressing potential endogeneity.

Keywords: Crude oil price uncertainty, asymmetric effect, corporate environmental responsibility, financial constraints.

JEL Categories: Q41, Q56, G31, G32.

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1 Introduction

The relationship between environmental sustainability and economic growth has been extensively discussed in the corporate environmental responsibility literature (CER). With increasing concerns about climate change and the need for a sustainable future, firms are now under immense pressure to adopt environmentally friendly practices and invest in sustainable innovations (Acheampong and Opoku, 2023). These investments, however, often come with costs that can be exacerbated by external shocks such as oil price volatility. Volatility in oil prices, which can result from either increases or decreases in prices, has the potential to affect corporate environmental behavior asymmetrically. Despite the attention given to the impact of oil prices on corporate environmental responsibility, the asymmetric effect of oil price volatility on CER remains underexplored.

In recent years, there has been growing recognition of corporations' responsibility to act in socially and environmentally responsible ways. This has led to the development of corporate social responsibility (CSR), with a significant focus on the environmental impact of corporations. Corporate environmental responsibility (CER) is now considered a vital component of CSR, reflecting the need for corporations to adopt environmentally sustainable practices and minimize their impact on the natural world. Consequently, environmentally responsible activities have become a crucial part of corporate strategy, with many companies actively pursuing initiatives to reduce their carbon footprint, conserve natural resources, and promote sustainability (Latapí Agudelo, Jóhannsdóttir and Davídsdóttir, 2019).

This paper utilizes real option theory to explain the relationship between oil price volatility and corporate environmental activities. Real option theory suggests that heightened uncertainty can impact corporations' decisions to invest in socially responsible activities (Phan, Tran, Tee and Nguyen, 2021). During periods of uncertainty, the option value of waiting to invest increases because corporations are unsure about the future profitability of their socially and environmentally responsible projects. As a result, they may choose to defer their responsible investments until oil price volatility subsides. When oil prices experience sudden shifts, businesses often face increased operational costs, prompting strategic adjustments. For instance, during periods of high oil prices, companies may prioritize investments in energy-efficient technologies or renewable energy sources to mitigate rising operational expenses. Conversely, when oil prices plummet, firms may scale back on environmental initiatives in favor of cost-saving measures (Herman, Nistor and Jula, 2023). Understanding these dynamics is crucial for comprehensively analyzing the impact of oil price volatility on corporate environmental behavior.

Phan et al. (2021) investigate the effect of overall oil price volatility (combining both increases and decreases in oil prices) on CSR and find a negative and significant relationship between oil price uncertainty and environmental, social, and governance engagement among oil and gas sector firms. However, their study does not account for the oil price uncertainty resulting specifically from increases versus decreases in oil prices, nor does it consider potential differences in impacts between oil and gas producers and firms in other sectors. Our study investigates how U.S. non-oil and gas producer corporations' environmental responsibility responds asymmetrically to positive and negative oil price fluctuations, while also testing financial constraints as a potential channel that explains this relationship.

Financial constraints significantly influence corporate environmental responsibility (CER) by affecting firms' ability to finance and implement environmental initiatives (Leong and Yang, 2021). Xu and Kim (2022) demonstrate that financial constraints increase the costs of financing such initiatives, leading to reduced investments in environmental activities and potentially higher pollution levels. This relationship suggests that financial constraints serve as a significant channel through which oil price volatility affects CER, as constrained firms may further curtail environmental investments in response to increased costs from positive oil price shocks. This highlights the critical role of financial health in sustaining corporate environmental commitments.

Our results show that a one standard deviation increase in oil volatility due to positive changes in oil prices leads to a 12.7% decline in the environmental score, while a similar rise in volatility from negative changes in oil prices corresponds to a 5.5% reduction. These results are robust to sector differences and a 2SLS estimation method addressing endogeneity. Additionally, our findings indicate that financial constraints serve as a potential channel through which oil price volatility influences environmental activities. Specifically, a one standard deviation increase in oil volatility from positive price changes leads to an 18% decrease in environmental score for firms with high financial constraints, compared to an 8% decrease for firms with low financial constraints. Furthermore, our findings reveal that firms in industries with high government spending exposure react more strongly to oil price volatility from increases in oil prices, indicating heightened sensitivity to economic uncertainties from oil price increases.

This study contributes to the existing finance literature by addressing the asymmetric effects of oil price volatility on corporate environmental responsibility (CER) among U.S. non-oil and gas producer firms. Unlike prior research, which often focuses on overall oil price volatility and its impact on oil and gas sector firms,[2] this study differentiates between positive and negative oil price changes and examines their distinct impacts on CER. Additionally, it highlights the role of financial constraints as a potential channel influencing these dynamics, while also exploring the implications of government spending exposure. Our research provides robust evidence on how oil price volatility affects firms differently based on their financial constraints and sectoral differences, offering valuable insights into the intersection of financial health, oil price fluctuations, and environmental initiatives.

The paper is structured as follows. Section 2 reviews the relevant literature and develops the hypothesis. Section 5 describes the research design and outlines the variables used in the analysis. Section 6 presents and discusses the results, while Section 7 outlines the robustness tests performed. Finally, Section 8 provides concluding remarks.

2 Related Literature and Hypothesis Development

Corporate environmental responsibility (CER) has become a crucial aspect of business operations in today's world. It is widely acknowledged that investment in CER can yield long-term benefits for firms (Gregory, Whittaker and Yan, 2016; Rjiba, Jahmane and Abid, 2020). However, these investment decisions are often complex due to the high level of uncertainty and irreversibility involved, particularly during times of economic instability.

The real options theory posits that in uncertain environments, such as those resulting from oil price volatility, the value of an investment opportunity is determined not only by the immediate

[2] For example, studies like Phan et al. (2021), and Hasan, Wong and Al Mamun (2022) focus on overall volatility rather than asymmetric volatility.

expected cash flows but also by the future opportunities the investment creates (Dixit, Dixit and Pindyck, 1994). This includes the option value of waiting. Hence, in situations of uncertainty, the ability to make future decisions can be considered a valuable option.

Applying real options theory to corporate environmental activities, it is plausible to hypothesize that firms facing significant oil price volatility may exhibit a reduced willingness to engage in environmental initiatives due to the associated uncertainty. Specifically, companies in oil-consuming industries may encounter elevated costs and financial risks from oil price fluctuations. As a result, they might prioritize short-term financial objectives over long-term investments in environmental sustainability. Delaying environmentally responsible investments to await more favorable information may be advantageous for firms in such circumstances (Cassimon, Engelen and Van Liedekerke, 2016; Husted, 2005; Rumokoy, Omura and Roca, 2023).[3]

Recent empirical studies, such as Phan et al. (2021), applying real options theory, have demonstrated a negative correlation between increased oil price volatility and corporate investments in environmentally responsible activities among oil and gas sector firms. However, these studies did not examine the asymmetric effect of oil price volatility on CER.

An interesting perspective emerges from a recent study by Maghyereh and Abdoh (2020), which found that corporate investments as measured by capital expenditures tend to decrease notably following periods of oil price volatility caused by increases, as opposed to decreases, in oil prices. The study argues that this asymmetry arises because future oil price increases are more likely following positive volatility, and vice versa. In the context of oil and gas consumers and their investments in environmentally responsible activities, rising crude oil prices lead to increased marginal production costs, reducing the expected profitability and net present value (NPV) of such investments. Conversely, declining oil prices correspond to higher expected profitability.

Consequently, when oil price volatility stems from negative price changes, the gap between waiting for more favorable conditions and the potential investment reward (NPV) becomes smaller. Conversely, if volatility arises from positive price changes, the gap widens. Therefore, the response of investments in environmentally responsible activities to oil price uncertainty is expected to be

[3]This approach enables firms to make informed decisions that enhance long-term growth prospects and bolster resilience to unexpected economic shocks.

lower when the uncertainty arises from negative price changes and higher when it originates from positive price changes.

Extending upon the current literature, we test the following hypothesis:

Hypothesis - The adverse effect of oil price uncertainty on environmentally responsible activities is more pronounced when the uncertainty results from increases in oil prices, whereas it is less pronounced when caused by decreases in oil prices.

3 Financial Constraints Channel

Oil price volatility can significantly impact a firm's financial constraints, ultimately influencing its corporate environmental responsibility (CER) initiatives. Christoffersen and Pan (2018) highlight that increased uncertainty during oil price fluctuations often leads to higher margin requirements, as lenders demand more collateral to mitigate risks. This tightening of financial constraints reduces the capital available for investments, including those in CER. Concurrently, financially constrained firms face limited access to resources for investment projects (Almeida and Campello, 2007), which diminishes their inclination towards CSR endeavors (Campbell, 2007; Chan, Chou and Lo, 2017). In the context of rising oil prices, firms may allocate more funds to energy-related costs, curtailing investments in environmentally responsible initiatives. Financially constrained firms, in particular, face heightened challenges, exacerbating the negative impact of oil price uncertainty on CER.

Financial constraints not only hinder CER investments but also disrupt the balance between the marginal cost of environmental activities and the expected legal liabilities reduction (Xu and Kim, 2022). During periods of high oil price volatility, financially constrained firms may further reduce their environmental investments due to elevated costs, magnifying the adverse effect on CER. The financial implications of oil price fluctuations, such as heightened operational costs, strain firms' financial resources (Kilian, 2008), limiting their capacity for long-term investments in environmental sustainability. Conversely, while decreases in oil prices may seem beneficial, associated volatility creates an uncertain financial environment, impeding firms' ability to secure financing for environmental projects. Importantly, the negative impact on CER is more pronounced with rising oil prices, as firms face immediate and severe financial pressure. Thus, stable financing conditions are crucial to sustain corporate environmental efforts, particularly during periods of oil price volatility.

4 Government Spending Exposure

Furthermore, this study aims to investigate how firms' exposure to government spending affects their response to asymmetric oil volatility and Corporate Environmental Responsibility (CER). Existing research, such as that by Belo, Gala and Li (2013), suggests that firms heavily reliant on government expenditures demonstrate unique reactions to economic shocks, which reflect their dependence on governmental policies and fiscal disbursements.

Government spending constitutes a significant proportion of the U.S. GDP, thereby exerting considerable influence on firms' cash flows and introducing uncertainty regarding future economic conditions (Alesina, 1987). This uncertainty, in turn, can influence firms' discount rates and expected profitability (Santa-Clara and Valkanov, 2003). Our study expands upon this framework to explore how firms' sensitivity to asymmetric oil price volatility and its impact on corporate environmental responsibility are influenced by their exposure to government spending.

Understanding this relationship is crucial as it sheds light on whether and how government spending moderates the effects of oil price volatility on firms' environmental responsibility practices. By examining firms with varying degrees of exposure to government spending, we can discern whether these companies exhibit different levels of responsiveness in their environmental strategies amid fluctuating oil prices. This research contributes to both academic CER literature and practical policymaking by elucidating the interconnected dynamics between government fiscal policies, oil market volatilities, and corporate environmental behaviors.

5 Research Design

5.1 Sample

In this study, we collect data from multiple sources. Specifically, we obtain firm-level financial data, environmental scores from the Datastream database for the period of 2002-2020 for U.S.

public firms. We exclude those firms in the oil and gas sector. This exclusion is crucial as it allows us to differentiate between oil and gas producers and consumers, whose responses to oil price volatility significantly vary. For producers, rising oil prices generally translate to increased profits, while declines lead to reduced profitability. Conversely, for consumers, higher oil prices escalate operational costs, whereas lower prices alleviate them. By focusing on firms predominantly reliant on oil and gas consumption, we can discern the unique impact of oil price volatility on this subset of businesses.

The study focuses on the US as one of the largest oil-consuming economies globally (International Energy Agency, 2021), enabling a detailed exploration of the research topic within a context that shapes global markets and policies. The decision to focus solely on the US was driven by the availability of comprehensive data, robust financial indicators, a supportive regulatory environment, and access to relevant data for channel testing. While acknowledging the significance of economies like China, they were not included due to differing regulatory and economic environments that could introduce methodological challenges and biases. It's important to note that the findings may not generalize to other global contexts beyond the scope of this specific analysis.

We collect West Texas Intermediate (WTI) crude oil price data from the Federal Reserve Bank of St. Louis and the economic policy uncertainty index from the dataset Baker, Bloom and Davis (2016). Additionally, we use inflation and GDP growth data from The World Database. To capture market volatility, we collect VIX data from the Chicago Board Options Exchange's CBOE Volatility Index, and the leading economic index is by the University of Michigan. Lastly, we employ oil price volatility structural break dates provided by Maghyereh and Abdoh (2020) to account for any potential changes in oil volatility over time. We use the availability of firms' environmental scores, as well as crude oil price data, to set the start date of our study. To ensure the focus of our study on oil consumers (rather than producers who benefit from oil price increases), we exclude firms classified as either oil equipment and services or oil and gas producers in the Datastream from our analysis. This approach acknowledges the divergent impact of oil price changes on these two groups and strengthens the robustness of our results. Our final dataset comprises 8,591 firm-year observations, covering 1,282 distinct companies operating in the US market. To mitigate any potential bias caused by outliers, we implement the winsorizing technique at the 1st and 99th percentiles for all variables, as recommended by Maghyereh and Abdoh (2020).

5.2 Variables Construction

5.2.1 Measuring Environmental Responsibility

This study explores the relationship between the asymmetric effect of oil price volatility and corporate environmental responsibility. The dependent variable, denoted as *EnviroScore*, serves as a measure of a firm's environmental responsibility. This score is derived from Refinitiv's Environment Pillar Score, a comprehensive metric that evaluates and aggregates a company's reported environmental performance across three key categories: emissions management, innovation in environmental practices, and efficient resource utilization.[4]

The Environment Pillar Score is calculated as a weighted average relative rating, considering various environmental indicators and performance metrics disclosed by the company. These indicators may include carbon emissions reduction initiatives, investment in renewable energy sources, adoption of sustainable production processes, and efforts to minimize waste generation. Each category is weighted according to its significance in assessing environmental performance, ensuring a holistic evaluation.

A higher *EnviroScore* indicates superior environmental stewardship and a stronger commitment to sustainable business practices. Firms with higher scores are deemed to have better overall environmental performance, reflecting proactive efforts to mitigate environmental impacts and promote ecological sustainability within their operations.

Furthermore, to validate our results and align with the increasing focus on carbon emissions, we incorporate the emission category of Refinitiv's Environment Pillar Score. The variable *Emission* measures a company's commitment and effectiveness in reducing environmental emissions during production and operational processes. This assessment provides insight into the company's efforts to mitigate its carbon footprint and other harmful emissions, enhancing the robustness of our analysis.

[4] Refinitiv's scores are widely used in the finance literature, as demonstrated by studies such as Phan et al. (2021) and Abdullah, Tiwari, Hossain and Abakah (2024).

5.2.2 Oil Price Volatility

To measure the annual oil price uncertainty for the period 2002-2020, we utilized the daily West Texas Intermediate (WTI) closing crude oil price contract and followed the approach of previous studies Maghyereh and Abdoh (2020); Phan et al. (2021) to compute the oil price uncertainty. The equation used to calculate $OilVol_t$ is:

$$OilVol_t = \sqrt{\frac{1}{N-1}\sum_{t=1}^{N}(r_t - E(r_t))^2} \times \sqrt{N}. \tag{1}$$

The daily oil return, denoted by r_t, is computed as $r_t = ln(P_t/P_{t-1})$, where P_t represents the West Texas Intermediate (WTI) closing crude oil price contract on day t, and P_{t-1} is the WTI closing crude oil price contract on the previous day $(t-1)$. The value of N corresponds to the number of trading days in a year.

In order to capture the asymmetric effect of oil price uncertainty on corporate environmental responsibility, we decompose the oil price uncertainty $OilVol_t$ into two components - positive return "upside" and negative return "downside". This decomposition is carried out following the approach of Barndorff-Nielsen, Kinnebrock and Shephard (2010) and adopted by Maghyereh and Abdoh (2020) , where the aggregate variance is split into positive and negative semi variance time series by aligning the variance estimates with periods of rising or falling oil prices. This is done in the following manner:

$$OilVol_t^{Pos} = \max\left\{OilVol_t^{Pos}, 0\right\} \Rightarrow OilVol_t^{Pos} = \begin{cases} OilVol_t & \text{if } r_t > 0 \\ 0 & \text{otherwise} \end{cases},$$

$$OilVol_t^{Neg} = \max\left\{OilVol_t^{Neg}, 0\right\} \Rightarrow OilVol_t^{Neg} = \begin{cases} OilVol_t & \text{if } r_t < 0 \\ 0 & \text{otherwise} \end{cases},$$

where, $OilVol_t^{Pos}$ and $OilVol_t^{Neg}$ represent the semivariance of oil returns in the right and left tails, respectively, during a specific time period (t). $OilVol_t^{Pos}$ captures the upside risk associated with positive movements in oil returns, while $OilVol_t^{Neg}$ measures the downside risk linked to negative movements in oil returns.

5.2.3 Financial Constraints Proxies

KZ Index

We employ highly used measure of financial constraint ($KZindex$) developed by Kaplan and Zingales (1997) and adopted by many studies including Di Giuli and Kostovetsky (2014); Ding, Gu and Peng (2022); Leong and Yang (2021). The $KZindex$ is based on the idea that financially constrained firms are more sensitive to changes in their cash flow than unconstrained firms. The index is calculated by regressing a firm's investment-to-cash flow sensitivity (ICFS) on a set of control variables, such as firm size, industry, and investment opportunities. The ICFS measures the extent to which a firm's investment is influenced by its cash flow. A higher $KZindex$ indicates a higher degree of financial constraint, meaning that the firm has limited access to external financing and is more reliant on its internal cash flow to fund its investment projects.[5]

Cost of Debt

We use the cost of debt variable (COD) alongside the $KZindex$ as a measure of financial constraints since financially constrained firms typically face higher borrowing costs. Financially constrained firms often encounter higher costs of debt because they are perceived as riskier borrowers by lenders. This perception stems from their limited access to capital and potential challenges in meeting debt obligations. Consequently, lenders may demand higher interest rates or impose stricter loan terms to offset the perceived risk. As a result, financially constrained firms tend to have higher costs of debt compared to their less constrained counterparts. To calculate a firm's average cost of debt (COD), following the methodology outlined by Frank and Shen (2016), we compute the ratio of its annual interest and related expenses to its total short and long-term debt.

[5]

$$KZindex = -1.001909 \times \frac{\text{CF}}{K} + 0.2826389 \times Q + 3.139193 \times \frac{\text{D}}{\text{TC}} + (-39.3678) \times \frac{\text{Div}}{K} + (-1.314759) \times \frac{\text{C}}{K}$$

where, cash flows (CF) are defined as income before extraordinary items plus total depreciation and amortization. K represents property, plant, and equipment from the previous period. Q is calculated as market capitalization plus total shareholder's equity minus book value of common equity and deferred tax assets, all divided by total shareholder's equity. Debt (D) includes total long-term debt, notes payable, and the current portion of long-term debt. TC represents total capital. Dividends (Div) refer to total cash dividends paid, both common and preferred. Cash (C) comprises cash and short-term investments.

5.2.4 Government Spending Exposure

Based on Belo et al. (2013), we adopt a measure of industry government spending exposure, quantifying the proportion of an industry's total output acquired for final use by the government sector (including federal, state, and local levels), both directly and indirectly. This measure provides insight into how susceptible industries are to changes in government expenditure. To explore the impact of this factor, we conduct a sub-sample analysis. We categorize firms based on their exposure to government spending into two groups: those with the highest government spending exposure (SIC codes 3721, 3812, 3731, 36, 1629, 1081, 3911, 3499, 3829, 3312) and those with the lowest exposure to government spending (SIC codes 5194, 2086, 2064, 518, 2389, 20, 5999, 7372, 9631, 1, 22).

5.3 Methodology

We first employ the following baseline regression model to test the effect of oil price volatility on corporate environmental responsibility:

$$\begin{aligned} Environment_{i,t} = \alpha_i + \beta_1 OilVol_{t-1} + \sum \beta_n \times CONTROLS_{i,t-1} + \sum \beta_n \times MACROS_{t-1} \\ + \sum \beta_n \times D_{r,t} + \epsilon_{i,t}. \end{aligned} \tag{2}$$

Second, we use the regression below and distinguish between the volatility as a result of increases ($OilVol^{Pos}$) and decreases ($OilVol^{Neg}$) in oil prices, and test,

$$\begin{aligned} Environment_{i,t} = \alpha_i + \beta_1 OilVol_{t-1}^{Neg} + \beta_2 OilVol_{t-1}^{Pos} + \sum \beta_n \times CONTROLS_{i,t-1} \\ + \sum \beta_n \times MACROS_{t-1} + \sum \beta_n \times D_{r,t} + \epsilon_{i,t}, \end{aligned} \tag{3}$$

where i indexes firms and t indexes year. Firm fixed effects are captured by α_i, and *Environment* is either the environmental score *EnviroScore*, or *Emission* as discussed in Section 5.2.1. Asymmetric oil price volatility is measured by $OilVol^{Neg}$ and $OilVol^{Pos}$, and the lagged oil price volatility is represented by $OilVol_{i,t-1}$, as developed in Section 5.2.2.

To control for other factors that may affect corporate environmental responsibility and innovation, we follow previous studies and include a matrix of firm-level explanatory variables denoted as $CONTROLS$, which includes variables such as firm size, profitability, leverage, dividend payout, market value to book value of assets ratio, and cash holdings (Arena, Michelon and Trojanowski, 2018; Ben-Amar, Chang and McIlkenny, 2017; Di Giuli and Kostovetsky, 2014; Phan et al., 2021). Unlike Phan et al. (2021), we do not include a year fixed effect as the oil price volatility variable is constant for all firm-year observations, and including it would reduce the explanatory power of the oil price volatility variable. The Appendix summarizes the definitions of the variables used in this study and the data sources.

We also account for macroeconomic conditions by including a matrix of macroeconomic variables, denoted as $MACROS$, in Equations (2) and (3). These variables include inflation, the leading economic index by the University of Michigan, GDP growth, market volatility, and economic policy uncertainty Das and Yaghoubi (2024). Additionally, we follow Maghyereh and Abdoh (2020) and consider the structural breaks in oil prices by including structural break dummies represented by $D_{r,t}$. These dummies capture crude oil price uncertainty and equal 1 during a specific period of a structural break, and 0 otherwise. In addition, to account for variations in firms, serial correlations, and heteroskedasticity in the error term $\epsilon_{i,t}$, we utilize cluster robust standard errors at the firm level.

5.4 Descriptive Statistics

Table 1 displays the Pearson's correlation coefficients among the main variables, revealing that the oil price volatility measure ($OilVol$) exhibits a negative correlation with both $EnviroScore$ and $Emission$. This finding supports the hypothesis that oil price volatility has a negative effect on corporate environmental responsibility, as previously noted by Phan et al. (2021). Notably, the negative correlation coefficients of $OilVol^{Pos}$ with the environmental variable is greater in magnitude than those of $OilVol$, whereas the correlation coefficients of $OilVol^{Neg}$ with the environmental variable is positive. This underscores the significance of distinguishing between the volatility of oil prices in terms of increases versus decreases and their distinct impacts on environmentally responsible initiatives. Furthermore, Table 1 reveals a negative correlation between the two measures of positive or negative oil volatility, which is consistent with the findings of Maghyereh and Abdoh (2020).

Table 2 presents a comprehensive summary of the key variables of interest, including their mean, standard deviation, quartiles, minimum and maximum values. To minimize potential bias due to outliers, all variables are winsorized at the top and bottom 1%. Both $EnviroScore$ and $Emission$ exhibit average scores around 25, indicating a moderate level of environmental responsibility among the companies surveyed. This suggests that while environmental considerations are being addressed, there remains room for improvement in terms of enhancing sustainability practices. The volatility of oil prices, as captured by $OilVol$, appears to be moderate, with a relatively low standard deviation (0.3). This suggests that while oil price fluctuations are observed, they are not excessively volatile within the sample period, potentially indicating a degree of stability in the oil market during this time. Turning to financial characteristics, the analysis reveals that firms in the sample exhibit a conservative approach to leverage, with an average debt-to-total-assets ratio of approximately 18%. The average cost of debt across the sample is approximately 6%, indicating the interest expenses incurred by firms on their outstanding debt obligations. Furthermore, the market-to-book ratio (MtB) sheds light on the valuation of firms relative to their book value of equity. With a mean value of 2.1 and a median value of 1.6, the majority of firms in the sample exhibit market valuations that exceed their book values, suggesting a tendency towards growth-oriented investments.

[Insert Tables 1 and 2 about here]

6 Empirical Results

We replicate current CER literature and explore the impact of oil price volatility on corporate environmental responsibility in columns (1) and (3) of Table 3. Additionally, we test our main hypothesis, which examines the asymmetric impact of oil volatility from increases versus decreases in oil prices in the market, in columns (2) and (4).

The table reveals a negative and statistically significant relationship between overall oil volatility ($OilVol$) and both $EnviroScore$ (Coefficient: -0.168; $p < 0.01$) and $Emission$ (Coefficient: -0.134; $p < 0.02$), supporting the notion that firms tend to postpone environmental initiatives when faced with uncertainty. Specifically, we find that a one standard deviation increase in $OilVol$ from the mean corresponds to a 6.1% decrease in $EnviroScore$ and a 4.9% decrease in $Emission$, as reported in Panel B.

In column (2), both $OilVol^{Neg}$ and $OilVol^{Pos}$ exhibit negative and statistically significant coefficients at the 1% level when using $EnviroScore$. However, in column (4), while the coefficient of $OilVol^{Neg}$ is not statistically significant, it is negative and statistically significant for $OilVol^{Pos}$ when using $Emission$. This observation implies that a positive change in oil prices (an increase in the oil price in the market) induces a more pronounced reduction in environmental activities compared to a negative change (a decrease in oil prices in the market).

These results imply that firms might adopt a reactive approach to environmental initiatives, scaling back efforts during periods of oil price increases to mitigate rising operational costs. Notably, a one standard deviation increase in $OilVol^{Neg}$ from the mean corresponds to a 5.5% decrease in $EnviroScore$, whereas a one standard deviation increase in $OilVol^{Pos}$ leads to a 12.7% decrease in $EnviroScore$, nearly double the reduction. Similarly, a one standard deviation increase in $OilVol^{Pos}$ results in an 11% decrease in $Emission$.

This finding underscores the strategic response of firms to fluctuations in oil prices, where they may prioritize short-term financial concerns over long-term environmental goals during periods of economic uncertainty. However, it also raises questions about the sustainability of such practices and the need for policies that incentivize firms to maintain consistent environmental stewardship despite external economic pressures.

Our findings advance the application of real options theory in understanding corporate environmental responsibility (CER) decisions amidst oil price volatility. We identify an asymmetric effect: firms significantly reduce engagement in environmentally responsible activities in response to volatility from increases in oil prices compared to decreases. This alignment with real options theory suggests that firms strategically delay investments in uncertain environments to maintain flexibility and improve decision-making. Specifically, our results indicate that during periods of positive oil price volatility, firms tend to defer CER initiatives more, anticipating better investment conditions ahead—a strategic response consistent with real options logic. By revealing these dynamics, our study enhances theoretical insights into corporate sustainability strategies amid economic uncertainty, providing valuable perspectives on how firms navigate environmental investments in volatile markets.

[Insert Table 3 about here]

Our baseline results suggest an asymmetric effect of oil price volatility on corporate environmental responsibility (CER). Specifically, the adverse impact of oil price uncertainty on environmentally responsible activities is more pronounced when the uncertainty results from increases in oil prices, while it is less pronounced when caused by decreases in oil prices.

Moreover, our study investigates financial constraints as a potential channel through which this asymmetric effect of oil price volatility on CER manifests. As explained in Section 3, during periods of high oil price volatility, financially constrained firms may further reduce their environmental investments due to elevated costs, thereby magnifying the adverse effect on CER. For our channel testing, we use two proxies for financial constraints: $KZindex$ and COD, as discussed in Section 5.2.3.

To facilitate our channel testing analysis and provide a more detailed interpretation of the coefficients while addressing measurement issues, we conduct a sub-sample analysis. Table 4 presents these findings. Columns (1) to (4) report results using the $EnviroScore$ variable, while columns (5) to (8) report results using the $Emission$ variable. We split our sample into quartiles based on financial constraints proxies, representing low and high financial constraint by the bottom and top 25% of values, respectively. Columns (1), (2), (5), and (6) utilize the $KZindex$, while columns (3), (4), (7), and (8) utilize COD. Odd-numbered columns represent firms in the bottom 25% of the sample in terms of financial constraint, while even-numbered columns represent firms in the top 25%.

In Table 4, we observe that $OilVol^{Neg}$ does not exhibit statistical significance across all specifications. However, we find a notable pattern with $OilVol^{Pos}$: its negative effect on environmental scores is significantly amplified for firms facing higher financial constraints. For instance, comparing the first two columns, a one standard deviation increase in $OilVol^{Pos}$ from its mean results in an 8.11% decrease in $EnviroScore$ for firms in the low financial constraint sub-sample using $KZindex$. In contrast, the same increase in $OilVol^{Pos}$ leads to a more substantial 17.91% decrease in $EnviroScore$ for firms in the high financial constraint sub-sample. This nearly twofold difference underscores the critical role of financial constraints in exacerbating the adverse impact of oil price volatility on corporate environmental responsibility.

[Insert Table 4 about here]

Table 5 presents the sub-sample analysis focusing on firms in the top 10 industries with the highest, and the top 10 industries with the lowest government spending exposure. Columns (1) and (3) report results for firms in sectors with the highest government spending exposure, while Columns (2) and (4) report results for firms in sectors with the lowest government spending exposure.

Our empirical findings consistently support two main conclusions. Firstly, across all columns (except Column (4)), we observe a statistically significant impact of ($OilVol^{Pos}$) on corporate environmental responsibility (CER). This finding underscores the robustness of our main results, highlighting that increases in oil prices lead to a notable decline in firms' environmental activities.

Secondly, firms operating in industries with high exposure to government spending demonstrate more pronounced reactions to oil price volatility compared to firms in industries with lower exposure. Specifically, during periods of oil price increases (as represented by $OilVol^{Pos}$), these firms experience more substantial reductions in their environmental initiatives. This outcome aligns with our conjecture that government spending exposure amplifies the negative effect of oil volatility on CER, reflecting heightened sensitivity to economic uncertainties associated with fluctuating oil prices within these sectors.

These results contribute to a deeper understanding of how external economic factors, such as government spending exposure and oil price volatility, interact to influence corporate environmental responsibility across different industry contexts.

[Insert Table 5 about here]

7 Robustness

7.1 Addressing Potential Endogeneity

One potential concern with our findings on the asymmetric effect of oil volatility on corporate environmental responsibility is the possibility of endogeneity. Specifically, certain country-level factors that vary over time, but were not included in our models, could affect both oil volatility and corporate environmental responsibility simultaneously, creating endogeneity. For instance, prior research has shown that firms tend to invest more in environmental initiatives during periods of economic slowdown (Harrison and Berman, 2016). While we have accounted for macroeconomic uncertainty in our models, it is possible that we have not fully captured the effects of the business cycle. To address this concern, we employ a Two-Stage Least Squares (2SLS) instrumental variable strategy, a widely-used approach for addressing endogeneity. Specifically, we use the t-2 value of the oil volatility variables as our instrumental variables, following the approach used in recent studies such as Maghyereh and Abdoh (2020), and Peng, Colak and Shen (2023).

Table 6 presents the results of our 2SLS analysis examining the relationship between asymmetric oil volatility and corporate environmental responsibility. The table consists of four panels. Panel A displays the first-stage regression results, while Panels B, C, and D report the second-stage regression results for the main hypothesis, the channel testing using $EnviroScore$, and the channel testing using $Emission$, respectively. Column (1) of Panel B presents the effect of oil volatility, while Column (2) represents the asymmetric effect of oil volatility using $OilVol^{Neg}$ and $OilVol^{Pos}$. Notably, after addressing the potential endogeneity issue, we continue to observe that the negative effect of oil price volatility from increases in oil prices is more pronounced than the negative effect of volatility from decreases in oil prices. For example, as reported in the table, the coefficient associated with $OilVol^{Pos}$ is -0.271, while the coefficient associated with $OilVol^{Neg}$ is -0.150. Furthermore, the Wald test statistics are statistically significant at the 1% level, indicating that we reject the null hypothesis ($H_0 : \beta_1^{Neg} = \beta_2^{Pos}$).

Panels C and D also provide support for the financial constraints channel testing. As shown in the tables, across all specifications in Panels C and D, the effect of oil volatility from increases in oil prices is more pronounced among firms with higher financial constraints, as measured by both $KZindex$ and COD.

Importantly, our regression results are supported by diagnostic tests that validate our findings. The under-identification test rejects the null hypothesis that our instrument is irrelevant, indicating that the instrumental variables used in our analysis are indeed exogenous to our model. Furthermore, the Cragg–Donald Wald F-statistic significantly exceeds the Stock and Yogo (2005) critical value of 16.38 at the 10% maximal IV size, thereby rejecting the null hypothesis that our instrument is weak. Consequently, our IV analysis corroborates the results of both our primary analysis and our examination of the financial constraints channel.

[Insert Table 6 about here]

7.2 Robustness to Sector Differences

A potential critique of our findings is that they may be driven primarily by firms in industries with the highest petroleum product consumption, as these firms would be most negatively affected by increases in oil prices. To address this concern, we conduct a sub-sample analysis to investigate whether our results are driven by firms in industries with the highest petroleum product consumption – specifically, firms belonging to 2-digit NAICS codes 31, 32, 33, 11, 21, 23, 48, and 49.[6]

Table 7 presents the results of this sub-sample analysis. Columns (1), (2), (5), and (6) use a sample of firms from high petroleum product consumption industries, while Columns (3), (4), (7), and (8) include the rest of the firms in our sample. Table 7 supports our primary findings, confirming the asymmetric impact of oil volatility on both analyzed sub-samples. We validate that these findings are robust and not disproportionately influenced by any particular sector or industry.

[Insert Table 7 about here]

[6] The U.S. petroleum products consumption by source and sector are from the U.S. Energy Information Administration (EIA) website.

8 Conclusion and Policy Implications

In this paper, we have investigated the asymmetric impact of crude oil price volatility on corporate environmental responsibility among U.S. public firms (excluding those in the oil and gas sector) over the period 2002-2020. Our study builds upon the work of Maghyereh and Abdoh (2020) by distinguishing between oil price uncertainty resulting from positive and negative oil price changes, examining financial constraints as a potential channel, and exploring the effect of government spending exposure on this relationship.

Our study contributes to the CER literature by being the first to document the asymmetric effect of oil price volatility on firms' environmental responsibility. We find that positive changes in oil prices have a more substantial negative impact on these outcomes compared to negative changes in oil prices. This suggests that oil price uncertainty has a differential impact on firms' environmental initiatives depending on the direction of the oil price change.

Additionally, we are the first to test financial constraints as a potential channel through which oil price volatility affects corporate environmental activities. Our results indicate that the effect of oil volatility from increases in oil prices is more pronounced among firms with higher financial constraints, as measured by two financial constraints proxies. Specifically, firms facing higher financial constraints may require additional support to enhance their environmental initiatives and innovation. These findings have important implications for policymakers, investors, and corporate managers who seek to promote sustainable economic growth.

Furthermore, we investigate how firms' exposure to government spending affects their sensitivity to oil price volatility. Consistent with previous literature on economic shocks and government spending exposure, our results indicate that the negative effect of oil volatility from increases in oil prices is more pronounced among firms in industries with the highest exposure to government spending.

Our study's findings are robust to endogeneity concerns and sectoral differences. By shedding light on the underlying mechanisms through which oil price uncertainty affects firms' environmental initiatives and innovation, our work offers valuable insights for understanding the impact of oil price volatility on these outcomes. Overall, our study highlights the importance of addressing the adverse and asymmetric effects of oil price uncertainty on firms' environmental responsibility to achieve sustainable economic growth.

This study's practical implications extend to strategic decision-making, risk management, financial planning, and competitive advantage. Firms can use insights on the asymmetric effects of oil price volatility to inform strategic decisions, adjust investment strategies, and mitigate risks associated with environmental initiatives. Financially constrained firms can enhance financial planning by understanding how oil price volatility affects environmental responsibility and innovation. Moreover, firms that effectively adapt to these dynamics may gain a competitive edge, attracting environmentally conscious investors and bolstering their market position. Overall, the study offers actionable insights for firms seeking to integrate environmental sustainability amidst the challenges of oil price uncertainty.

In addition, this study's findings hold significant social implications. By shedding light on how oil price volatility affects corporate environmental responsibility and innovation, it contributes to broader sustainability efforts. Firms adapting their practices in response to oil price dynamics can positively impact the environment and communities by reducing carbon emissions, conserving resources, and fostering innovation in sustainable technologies. Additionally, heightened awareness of these issues may stimulate public discourse on the intersection of economic factors and environmental outcomes, encouraging greater societal engagement in promoting sustainable business practices.

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Table 1: Correlations

The table presents the pairwise correlations among the variables analyzed in this study. For a detailed explanation of the variables, refer to Section 5 and Appendix A. The row and column headings correspond to the reference numbers assigned to each variable, and the values in the table represent the correlation coefficients. * and ⋄ indicate 5%, and 10% significance levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) $EnviroScore$	1										
(2) $Emission$	0.9019*	1									
(3) $OilVol$	-0.0274*	-0.0182	1								
(4) $OilVol^{Neg}$	0.0708*	0.0522*	0.2836*	1							
(5) $OilVol^{Pos}$	-0.0863*	-0.0625*	0.2844*	-0.8387*	1						
(6) $Size$	0.5661*	0.5522*	0.0115	0.0645*	-0.0579*	1					
(7) ROA	0.00700	-0.00260	0.000500	0.0124	-0.0121	0.0510*	1				
(8) $Leverage$	0.1082*	0.0803*	0.0721*	0.0610*	-0.0201*	0.3177*	-0.00500	1			
(9) MtB	-0.1396*	-0.1092*	-0.0713*	-0.0704*	0.0298*	-0.3333*	-0.0427*	-0.5109*	1		
(10) $Cash$	-0.2326*	-0.1944*	-0.0307*	-0.0365*	0.0190	-0.4790*	-0.2785*	-0.4524*	0.4918*	1	
(11) Div	0.3176*	0.2909*	-0.0199	0.0336*	-0.0450*	0.2236*	0.0899*	-0.1426*	0.1218*	-0.1281*	1

Source: Authors own creation

Table 2: Summary Statistics
The table provides summary statistics for the variables examined in this study. Prior to computing the summary statistics, all variables were winsorized at the 1% level in both tails of the distribution to minimize the influence of extreme values. See Section 5 and Appendix A for the discussion on the variables.

Variable	N	Mean	p25	p50	p75	Max	Min	SD
$EnviroScore$	11887	25.01	0	14.92	45.56	89.01	0	27.21
$Emission$	11887	25.13	0	9.570	46.98	97.69	0	30.78
$OilVol$	11887	0.442	0.279	0.334	0.482	1.311	0.181	0.307
$OilVol^{Neg}$	11887	0.257	0	0	0.308	1.311	0	0.394
$OilVol^{Pos}$	11887	0.185	0	0.241	0.339	0.515	0	0.186
$Size$	11887	7.918	7.005	8.007	8.986	10.26	0.795	1.505
ROA	11338	1.078	0.588	0.886	1.342	5.373	0	0.775
$Leverage$	11887	0.182	0.0412	0.139	0.268	0.874	0	0.175
MtB	10950	2.159	1.048	1.595	2.589	10.93	0.281	1.761
$Cash$	11887	0.205	0.0497	0.125	0.275	0.937	0.000329	0.218
Div	11338	0.0156	0	0.00443	0.0237	0.109	0	0.0230
$Inflation$	11887	1.849	1.262	1.812	2.443	3.839	-0.356	0.941
LEI	11887	99.23	90.67	100.3	106.0	111.5	77	9.555
$GDPg$	11887	1.546	1.710	2.160	2.850	3.800	-3.400	2.029
Vix	11887	17.24	12.65	14.69	19.69	32.87	10.60	6.158
EPU	11887	1.330	1.114	1.199	1.439	2.430	0.713	0.441
COD	10237	0.0663	0.0335	0.0482	0.0651	1.831	0.00228	0.140
$KZindex$	11882	0.444	-0.0715	0.502	1.097	3.352	-3.898	1.100

Source: Authors own creation

Table 3: Asymmetric Oil Price Volatility and Corporate Environmental Responsibility
This table examines the relationship between asymmetric oil price volatility and corporate environmental responsibility (CER) using data from U.S. public firms (excluding oil and gas industry firms) from 2002 to 2020. Panel A presents the estimation results of Equations (2) and (3), utilizing *EnviroScore* and *Emission* as measures of CER. Columns (1) and (3) test the effect of $OilVol$ and replicate the results of existing literature, while Columns (2) and (4) employ the asymmetric oil volatility measures $OilVol^{Neg}$ and $OilVol^{Pos}$ to test the main hypothesis of this study. Panel B reports the economic importance of oil volatility variables by estimating the percentage change in the dependent variables due to a one standard deviation increase in the oil volatility measures. The table also presents clustered standard errors by firm in parentheses, with significance levels denoted by ***, **, and * for 1%, 5%, and 10%, respectively. For a comprehensive description of the variables, see Section 5 and Appendix A.

Panel A				
	(1)	(2)	(3)	(4)
VARIABLES	*EnviroScore*		*Emission*	
$OilVol$	-0.168***		-0.134***	
	(0.018)		(0.023)	
$OilVol^{Neg}$		-0.087***		-0.037
		(0.022)		(0.028)
$OilVol^{Pos}$		-0.199***		-0.171***
		(0.018)		(0.023)
$Size$	5.324***	5.239***	7.961***	7.858***
	(0.926)	(0.927)	(1.137)	(1.137)
ROA	0.869	0.910	0.301	0.350
	(0.893)	(0.889)	(1.038)	(1.033)
$Leverage$	-2.070	-1.942	0.710	0.864
	(2.139)	(2.142)	(2.660)	(2.662)
Div	49.981*	49.313*	60.434*	59.635*
	(26.325)	(26.253)	(32.009)	(31.906)
MtB	0.124	0.134	-0.033	-0.021
	(0.288)	(0.288)	(0.378)	(0.377)
$Cash$	4.086	3.589	4.174	3.581
	(3.052)	(3.061)	(3.684)	(3.685)
$Inflation$	-3.511***	-0.939*	-2.259***	0.818
	(0.398)	(0.502)	(0.480)	(0.616)
LEI	0.805***	1.130***	0.831***	1.218***
	(0.067)	(0.087)	(0.087)	(0.114)
$GDPg$	-6.540***	-6.442***	-5.722***	-5.604***
	(0.397)	(0.396)	(0.462)	(0.459)
EPU	-14.201***	-6.179***	-10.732***	-1.137
	(2.028)	(2.190)	(2.362)	(2.547)
Vix	-0.019	0.742***	0.215**	1.125***
	(0.069)	(0.126)	(0.086)	(0.163)
$D1$	17.757***	6.888***	13.880***	0.881
	(1.574)	(2.057)	(1.851)	(2.448)
$D2$	35.626***	28.566***	30.236***	21.794***
	(2.320)	(2.335)	(2.680)	(2.648)
$D3$	19.287***	24.222***	18.058***	23.959***

Table 3 (*continued*)				
	(1)	(2)	(3)	(4)
VARIABLES	*EnviroScore*		*Emission*	
	(1.025)	(1.349)	(1.261)	(1.728)
$D4$	22.584***	25.253***	22.789***	25.980***
	(1.355)	(1.430)	(1.706)	(1.829)
$D5$	30.069***	24.320***	28.769***	21.893***
	(1.722)	(1.861)	(2.123)	(2.267)
Constant	-72.547***	-129.788***	-108.363***	-176.819***
	(8.960)	(12.747)	(11.519)	(16.408)
Firm fixed effect	Yes	Yes	Yes	Yes
chi2		67.91		58.37
		0.000		0.000
Observations	8,591	8,591	8,591	8,591
R-squared	0.843	0.844	0.813	0.814
Panel B - marginal effect				
$OilVol$	-6.1%		-4.9%	
$OilVol^{Neg}$		-5.5%		NA%
$OilVol^{Pos}$		-12.8%		-11.0%

Source: Authors own creation

Table 4: Asymmetric Effects of Oil Price Volatility on Firms with High and Low Financial Constraints

This table presents the results of examining the asymmetric impact of oil price volatility on environmental score ($EnviroScore$) for firms with high and low financial constraints. The firms are categorized into high and low financial constraints based on the median of $KZindex$. Panel A presents the estimation results for Equations (2) and (3). Panel B reports the economic importance of oil volatility variables by estimating the percentage change in the dependent variables due to a one standard deviation increase in the oil volatility measures. Columns (1) and (2) test the effect of $OilVol$, while Columns (3) and (4) examine the asymmetric effect of oil volatility using $OilVol^{Neg}$ and $OilVol^{Pos}$ under low and high financial constraints. The table presents clustered standard errors by firm in parentheses, and the significance levels are denoted by ***, **, and * for 1%, 5%, and 10%, respectively. For a comprehensive description of the variables, please see Section 5 and Appendix A.

Panel A								
	KZindex		*COD*		*KZindex*		*COD*	
	Low	High	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	*EnviroScore*				*Emission*			
$OilVol^{Neg}$	-0.087	-0.052	-0.021	-0.035	-0.001	0.029	0.060	0.015
	(0.050)	(0.060)	(0.052)	(0.059)	(0.070)	(0.076)	(0.070)	(0.069)
$OilVol^{Pos}$	-0.160***	-0.198***	-0.110***	-0.194***	-0.097*	-0.125**	-0.058	-0.152**
	(0.040)	(0.044)	(0.040)	(0.055)	(0.051)	(0.058)	(0.052)	(0.067)
$Size$	6.339**	3.562***	5.906***	4.558**	8.848***	5.114***	9.808***	6.876**
	(2.736)	(1.290)	(1.658)	(2.288)	(2.935)	(1.512)	(2.179)	(2.710)
ROA	-0.136	1.629	1.869	0.718	-2.411	1.662	0.828	0.616
	(2.411)	(1.307)	(1.242)	(1.696)	(3.022)	(1.449)	(1.766)	(1.972)
$Leverage$	1.444	-5.216*	-6.870*	-5.224	12.776**	-7.153**	-3.469	-5.458
	(5.618)	(2.686)	(3.826)	(3.851)	(6.372)	(3.336)	(4.680)	(5.442)
Div	94.424***	10.754	57.274	35.502	100.348**	-0.569	41.336	35.909
	(36.466)	(52.217)	(44.833)	(36.036)	(42.581)	(49.839)	(61.374)	(39.032)
MtB	-0.057	-0.147	-0.018	-0.594	-0.312	0.148	-0.163	-0.171
	(0.748)	(0.425)	(0.334)	(0.496)	(0.947)	(0.543)	(0.447)	(0.649)
$Cash$	1.424	6.191	5.115	-8.072	6.217	5.530	7.326	-13.027*
	(6.755)	(5.564)	(4.820)	(7.802)	(7.958)	(5.857)	(6.102)	(7.717)
$Inflation$	-1.987*	0.381	-0.929	-0.058	0.122	1.523	1.119	1.946
	(1.153)	(1.227)	(1.086)	(1.168)	(1.552)	(1.503)	(1.346)	(1.372)
LEI	0.724***	1.530***	1.104***	1.435***	0.788***	1.747***	1.098***	1.515***
	(0.184)	(0.220)	(0.212)	(0.223)	(0.255)	(0.252)	(0.283)	(0.277)
$GDPg$	-6.116***	-6.275***	-5.039***	-6.186***	-4.730***	-5.655***	-4.028***	-5.481***
	(0.865)	(0.819)	(0.824)	(0.761)	(0.981)	(0.868)	(0.973)	(0.841)
EPU	-13.415***	0.490	-0.976	-0.481	-8.425	6.807	3.466	1.282

Table 4 (*continued*)

	KZindex		*COD*		*KZindex*		*COD*	
	Low	High	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	*EnviroScore*				*Emission*			
	(4.628)	(5.164)	(4.496)	(4.652)	(6.070)	(5.760)	(5.615)	(5.161)
Vix	0.254	1.246***	0.661**	1.048***	0.763*	1.481***	0.925**	1.410***
	(0.274)	(0.329)	(0.296)	(0.316)	(0.390)	(0.397)	(0.388)	(0.368)
$D1$	10.194**	1.481	5.535	0.557	2.495	-4.110	-3.293	-4.809
	(4.613)	(5.043)	(4.365)	(4.328)	(6.167)	(5.754)	(5.557)	(4.902)
$D2$	30.835***	24.161***	23.669***	25.325***	21.942***	20.008***	16.714***	19.584***
	(5.074)	(5.006)	(4.685)	(4.695)	(6.166)	(5.422)	(5.503)	(5.312)
$D3$	18.922***	29.126***	22.410***	27.376***	18.597***	30.608***	22.701***	25.836***
	(2.864)	(3.759)	(3.208)	(3.181)	(3.804)	(4.062)	(4.156)	(3.818)
$D4$	21.283***	30.104***	21.651***	24.524***	19.658***	31.395***	22.450***	25.185***
	(2.906)	(3.988)	(3.254)	(3.567)	(3.894)	(4.493)	(4.063)	(4.550)
$D5$	24.495***	24.422***	18.051***	17.302***	18.288***	22.064***	15.619***	14.676***
	(3.845)	(5.105)	(4.186)	(4.494)	(5.413)	(5.916)	(5.429)	(5.400)
Constant	-74.717**	-180.222***	-146.167***	-163.224***	-121.653***	-230.916***	-189.659***	-203.237***
	(31.387)	(31.826)	(26.754)	(29.502)	(42.144)	(38.364)	(37.964)	(36.698)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,180	1,804	1,842	1,772	2,180	1,804	1,842	1,772
R-squared	0.876	0.839	0.875	0.847	0.851	0.815	0.844	0.840
Panel B - marginal effect								
$OilVol^{Neg}$	NA	NA	NA	NA	NA	NA	NA	NA
$OilVol^{Pos}$	-8.11%	-17.91%	-10.8%	-14.0%	-5%	-12%	NA	-11%

Source: Authors own creation

Table 5: Impact of Oil Price Volatility on Firms with High and Low Government Spending Exposure

This table presents the results of sub-sample analysis focusing on firms in industries with the highest and lowest government spending exposure. Columns (1) and (3) report results for firms in sectors with the highest government spending exposure, while Columns (2) and (4) report results for firms in sectors with the lowest government spending exposure. The table presents clustered standard errors by firm in parentheses, and significance levels are denoted by ***, **, and * for 1%, 5%, and 10%, respectively. For a comprehensive description of the variables, refer to Section 5 and Appendix A.

Panel A				
	High	Low	High	Low
	(1)	(2)	(3)	(4)
VARIABLES	$EnviroScore$		$Emission$	
$OilVol^{Neg}$	-0.145**	-0.059	-0.117*	0.119
	(0.063)	(0.103)	(0.069)	(0.152)
$OilVol^{Pos}$	-0.202***	-0.189**	-0.178***	-0.094
	(0.057)	(0.072)	(0.066)	(0.098)
Constant	-98.880***	-132.998**	-152.458***	-204.795**
	(36.817)	(64.487)	(48.547)	(86.683)
Controls	Yes	Yes	Yes	Yes
Macros	Yes	Yes	Yes	Yes
Structural Dummies	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes
Observations	960	619	960	619
R-squared	0.840	0.862	0.833	0.804
Panel B - marginal effect				
$OilVol^{Neg}$	-8%	NA	-7%	NA
$OilVol^{Pos}$	-12%	-10%	-10%	NA

Source: Authors own creation

Table 6: Robustness Check using Alternative Estimation Method: Two-Stage Least Squares (2SLS)
This table presents the results of re-examining this studies' main Hypothesis as developed in Section 2, and the financial constraints channel as discussed in Section3 using a Two-Stage Least Squares (2SLS) model to address potential endogeneity. We employ the lag (t-2) of the oil volatility variables as instrumental variables (Maghyereh and Abdoh, 2020). Panel A reports the first-stage results, Panel B reports the second-stage results testing the assymetric effect of oil price volatility. Panel C, reports the second stage results of the financial constraints channel testing *EnviroScore*, and Panel D reports the second stage results of the financial constraints channel testing *Emission*. The table presents clustered standard errors by firm in parentheses. Significance levels are denoted by ***, **, and * for 1%, 5%, and 10%, respectively. For a comprehensive description of the variables, please see Section 5 and Appendix A.

Panel A: 2SLS first stage			
	l.OilVol	*l.OilVolNeg*	*l.OilVolPos*
	(1)	(2)	(3)
L2.OilVol2	-1.338***		
	0.000		
L2.OilVolNeg2		-0.079***	
		0.000	
L2.OilVolPos2			-0.749***
			0.000
Firm FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Macros & Structural Dummies	Yes	Yes	Yes
Cragg-Donald Wald F statistic	10280.61	1289.28	1289.28
Observations	7452	7452	7452
Underidentification Test: 2-statistic	12858	8949	10639
p-value	0.000	0.000	0.000
Weak Instrument Test: F-statistic	12820	4786	4786

Panel B : 2SLS second stage - asymmetric effect of oil price volatility				
	(1)	(2)	(3)	(4)
VARIABLES	*EnviroScore*		*Emission*	
$OilVol$	-0.229***		-0.209***	
	(0.029)		(0.037)	
$OilVol^{Neg}$		-0.150***		-0.125***
		(0.036)		(0.047)
$OilVol^{Pos}$		-0.271***		-0.254***
		(0.027)		(0.034)
Controls	Yes	Yes	Yes	Yes
Macros	Yes	Yes	Yes	Yes
Structural Dummies	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes
$W\beta(\chi^2)$		40.19		25.29
		0.000		0.000
Observations	7,452	7,452	7,452	7,452
R-squared	0.485	0.483	0.394	0.393

Panel C : 2SLS second stage - financial constraints channel using $EnviroScore$				
	(1)	(2)	(3)	(4)
	$KZindex$		COD	
VARIABLES	Low	High	Low	High
$OilVol^{Neg}$	-0.144*	-0.252**	-0.164*	-0.187*
	(0.075)	(0.098)	(0.097)	(0.100)
$OilVol^{Pos}$	-0.209***	-0.360***	-0.216***	-0.312***
	(0.059)	(0.069)	(0.068)	(0.079)
Controls	Yes	Yes	Yes	Yes
Macros	Yes	Yes	Yes	Yes
Structural Dummies	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes
$W\beta(\chi^2)$	3.57	4.21	0.97	4.37
	0.058	0.040	0.325	0.036
Observations	1,946	1,512	1,485	1,484
R-squared	0.415	0.447	0.425	0.387

Panel D: 2SLS second stage - financial constraints channel using $Emission$				
	(1)	(2)	(3)	(4)
	$KZindex$		COD	
VARIABLES	Low	High	Low	High
$OilVol^{Neg}$	-0.016	-0.171	-0.109	-0.197*
	(0.093)	(0.128)	(0.122)	(0.115)
$OilVol^{Pos}$	-0.118*	-0.282***	-0.162**	-0.297***
	(0.069)	(0.086)	(0.082)	(0.096)
Controls	Yes	Yes	Yes	Yes
Macros	Yes	Yes	Yes	Yes
Structural Dummies	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes
$W\beta(\chi^2)$	5.02	NA	NA	2.4
	0.025	NA	NA	0.123
Observations	1,946	1,512	1,485	1,484
R-squared	0.291	0.394	0.357	0.283

Source: Authors own creation

Table 7: Robustness Check - Sector Differences

This table presents the results of examining the impact of oil price volatility on $EnviroScore$ and $Emission$ using sub-sample analysis. Firms are categorized into high and low petroleum consumption sectors based on their NAICS codes. Columns (1), (2), (5) and (6) use a sample of firms in high petroleum products consumption sectors, while Columns (3), (4), (7) and (8) use the rest of the firms. The table presents clustered standard errors by firm in parentheses, and the significance levels are denoted by ***, **, and * for 1%, 5%, and 10%, respectively. For a comprehensive description of the variables, please see Section 5 and Appendix A.

	Petroleum products consumption							
	High		Low		High		Low	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	$EnviroScore$				$Emission$			
$OilVol$	-0.161***		-0.175***		-0.119***		-0.159***	
	(0.023)		(0.031)		(0.029)		(0.039)	
$OilVol^{Neg}$		-0.094***		-0.064*		-0.037		-0.031
		(0.027)		(0.037)		(0.035)		(0.047)
$OilVol^{Pos}$		-0.187***		-0.215***		-0.150***		-0.205***
		(0.022)		(0.030)		(0.028)		(0.039)
Constant	-79.075***	-125.867***	-58.526***	-137.226***	-119.928***	-177.282***	-88.076***	-179.007***
	(11.279)	(16.350)	(14.611)	(19.626)	(14.820)	(21.606)	(17.716)	(23.955)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macros	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Structural Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$W\beta(\chi^2)$		29.08		48.88		26.36		37.97
		0.000		0.000		0.000		0.000
Observations	5,454	5,454	3,137	3,137	5,454	5,454	3,137	3,137
R-squared	0.842	0.842	0.842	0.843	0.817	0.818	0.810	0.811

Source: Authors own creation

9 Appendix A

The following table presents the definitions of the variables used in our analysis. The first two columns provide the variable name and its definition, while the third column indicates the source of the data.

Variable	Definition	Data Sources
$OilVol$	The annual oil price uncertainty for the period 2002-2020, constructed in Section 5.2.2.	Federal Reserve Bank of St. Louis
$OilVol^{Neg}$	The semivariance of oil returns in the left tail, constructed in Section 5.2.2.	Federal Reserve Bank of St. Louis
$OilVol^{Pos}$	The semivariance of oil returns in the right tail, constructed in Section 5.2.2.	Federal Reserve Bank of St. Louis
$EnviroScore$	The Refinitiv's Environment Pillar Score, which is a weighted average relative rating of a company's reported environmental information across three categories: emissions, innovation, and resource use.	Datastream
$Emission$	Measures a company's commitment and effectiveness towards reducing environmental emissions in the production and operational processes.	Datastream
ROA	The ratio of operating income before depreciation to total assets as an indicator of firms' profitability.	Datastream
$Size$	The logarithm of a firm's total assets.	Datastream
MtB	The market-to-book ratio, which is calculated as the ratio of a firm's market value of equity to its book value of equity, as an indicator of firms' financial performance and growth prospects.	Datastream
$Leverage$	The ratio of total liabilities to total assets as an indicator of firms' leverage and financial risk Keefe and Yaghoubi (2016).	Datastream
Div	A firm's annual dividend payment as a measure of its dividend policy	Datastream
$Cash$	The ratio of cash and marketable securities to total assets as an indicator of firms' liquidity and ability to meet short-term obligations Yaghoubi and Keefe (2022).	Datastream
Vix	The CBOE Volatility Index, also known as the VIX, which is calculated by the Chicago Board Options Exchange, as a measure of market volatility.	Chicago Board Options Exchange
LEI	The Leading economic index representing the global economic movements, developed by the University of Michigan.	The Conference Board.
$Inflation$	The US inflation rate.	The World Bank Database
$GDPg$	The annual U.S. GDP growth.	The World Bank Database
EPU	The newspaper based economic policy uncertainty variable constructed by Baker et al. (2016).	Federal Reserve Bank of St. Louis
$D1$ to $D5$	The structural break dates provided by Maghyereh and Abdoh (2020).	

Variable	Definition	Data Sources
$KZindex$	A measure of financial constraint developed by Kaplan and Zingales (1997). Section 5.2.3 discuss the variable.	Datastream
COD	Represents the cost of debt and is the ratio of a firm's annual interest and related expenses to its total short and long-term debt.	Datastream

Source: Authors own creation