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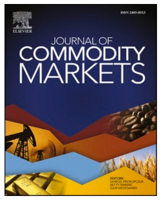

Regular article

Do oil market shocks affect financial distress? Evidence from firm-level global data

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A B S T R A C T

This study investigates the impact of three oil price shocks on financial distress of global firms using a dataset of 8130 firms across 48 countries from 2002 to 2022. It also analyses the role of energy diversification in the relationship between oil shocks and firm distress. The findings reveal that aggregate demand and specific demand shocks increase firm distress risk, while supply shocks reduce it. Furthermore, the results suggest that energy diversification mitigates the impact of specific demand shocks on firm distress. The study also implements several robustness checks, and the results remain consistent. Potential policy implications are also discussed.

1. Introduction

Firm distress risk arises when a company faces significant challenges in paying off its debts and carrying on with its operations as usual, which could lead to bankruptcy or insolvency. Previous studies have decisively suggested the impact of macroeconomic indicators, such as economic growth (Wong et al., 2010), interest rates (Liu, 2004), exchange rates (Chatziantoniou et al., 2023), and inflation rates (Khoja et al., 2019) on the distress risk of firms. Generally, the literature suggests that economies with weak economic fundamentals, such as slowing growth, high real interest rates, and inflation, or declining competitiveness in international trade, as indicated by a higher real exchange rate, are more likely to magnify an initial adverse shock and cause distress for systemic firms.

Energy shocks can also directly affect firm performance through production costs and cash flow barriers, and they can also have an indirect impact through macroeconomic factors. For instance, Hamilton (1983, 1996) explored the effects of energy price changes on economic activity. Several studies have also demonstrated a significant relationship between energy price shocks and stock market returns (Demirer et al., 2020; Le and Chang, 2015; Luo and Qin, 2017; Park and Ratti, 2008), as well as between energy price shocks and firm financial performance and investment (Gupta, 2016; Lee and Lee, 2019; Ma et al., 2021; Phan et al., 2019). Energy price shocks also substantially affected credit risk exposure (Bajaj et al., 2023; Figlewski et al., 2012; Pesaran et al., 2006). Therefore, changes in macroeconomic conditions and stock market performance triggered by energy price shocks could increase a firm's credit risk exposure and lead to distress. This is consistent with numerous prior studies demonstrating the sensitivity of firm distress to macroeconomic factors (Carling et al., 2007; Duffie et al., 2007), highlights the imperative need for a thorough investigation.

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Despite the growing body of research on firm distress and the macroeconomic impact of oil uncertainty on firm performance and investment, little attention has been paid to understanding the effect of oil price uncertainty on distress risk at the firm level. Notable exceptions include Khoja et al. (2019), who consider oil prices to be a feature in predicting firm distress and discovered that financial distress can arise in various dynamic settings, with the understanding of its complexities requiring consideration of both industrial characteristics and macroeconomic indicators such as inflation rates, interest rates, and oil prices.

This study addresses several unresolved questions about the relationship between crude oil uncertainty and firm-level distress risk while adding to the scant literature on the subject. Specifically, this study provides insights into the following questions: How do oil price shocks affect global firm distress risk? Is this relationship consistent between developed and developing countries and across different continents? Is this relationship homogenous across different firm characteristics? Does this relationship differ for oil consumers and oil producers? What impact have global financial crises and periods of market turbulence had on this relationship? Finally, does energy diversification at the country level moderate this impact?

At this stage, the dataset used in this study includes 8130 firms from 48 different countries, for a total of 80,151 firm-year observations from 2002 to 2022. Our research contributes to understanding how oil price shocks affect firm-level distress risk in three ways.

Firstly, to our knowledge, no study has considered the impact of oil price uncertainties on firm-level distress risk. While specific studies (e.g., Khoja et al., 2019) have incorporated oil price as a macroeconomic indicator, their analysis has been mainly focused on price considerations. In contrast, our study examines how various oil price shocks – i.e., supply shock, aggregate demand shock, and specific demand shock – may affect firm distress.

Secondly, this study is the first to examine how the impact of crude oil shocks on firm distress risk is sensitive to regions, countries, and firm characteristics. For instance, Phan et al. (2019) documented how the effect of crude oil on company investment varies depending on the region and market. Additionally, Phan et al. (2019), Sadorsky (2006), and Tsai (2015) explored how the effect of crude oil on stock markets is sensitive to firms' characteristics. We contribute to the literature by addressing this question. We also divided the sample firms into developed, emerging, Africa, the Americas, Asia, Australasia, and Europe aggregate market sample segments. The effects of oil shocks may differ among these markets due to the differences in national industrial structure, energy composition, and energy consumption patterns.

Thirdly, this study examines the moderating impact of a country's energy diversification on the relationship between oil price shocks and firm financial distress. Previous studies (Gozgor and Paramati, 2022; Mania and Rieber, 2019) have underscored the importance of energy diversification in building a sustainable economy, promoting economic growth, and mitigating the adverse effects of external shocks on financial performance. This study adds to the literature by highlighting how a country's energy diversification may affect a firm's sensitivity to energy price shocks.

We use the Distance to Default (*DD*) concept, a key measure derived from Merton's (1974) approach, to measure company distress. As emphasized in the prior literature (Andreou et al., 2021), DD provides a robust framework for evaluating a company's vulnerability to financial distress. Notably, Hillegeist et al. (2004) underlined the efficiency of Merton's (1974) DD model by using real-time information about a company's financial condition compared to traditional rating models that rely on accounting data. Using the Merton approach, we calculated a company's distress risk level to be the probability of default, building on the insights of Bharath and Shumway (2008).

To measure oil price shocks, we followed Kilian's (2009) methodology to decompose oil shocks into their components, namely Supply Shocks, Aggregate Demand Shocks, and Specific (Cautionary) Demand Shocks. Kilian highlighted the need to differentiate between these supply and demand issues. Empirical analysis using Structural Vector Autoregression (SVAR) indicates that oil shocks affect economic indices and companies differently.

The empirical findings indicate that while the oil supply shock negatively and significantly affects a firm's distress risk, oil aggregate and specific demand shocks positively and substantially impact firm distress. These findings are robust across most panels except for Africa, where no significant effect of oil shocks on firm distress is observed. For firms in the crude oil industry or oil-producing countries, there is a reduction in the impact of specific demand shocks on firm distress. Also, the effect is more substantial during financial crises. Except for Africa, where oil shocks have no significant impact on firm distress, these findings are consistent for most panels. Specific demand shock exerts less impact on the distress risk of firms in the crude oil industry or oil-producing nations. Furthermore, the results suggest that energy diversification mitigates the effect of the demand shock on firms' distress risk in oil -producing nations. In the global and American regions, firms in nations with a broader range of energy sources are less vulnerable to the risk of financial distress caused by oil demand shocks. On the other hand, energy diversification increases the negative effect of specific demand shocks on firms' distress in emerging markets, as well as the Asia, Africa, and oil-consumer regions.

The rest of this paper is structured as follows. Section 2 provides a review of the literature and develops the hypotheses. Section 3 outlines the methodology employed in this study. Section 3 also provides a detailed description of the data. Section 4 reports and discusses the empirical findings. Section 5 concludes the paper.

2. Literature review and hypotheses development

When analyzing the impact of oil prices on firm performance, the existing literature reveals two distinct perspectives: macroeconomic effects and direct firm-level consequences. The former, which impacts the macroeconomic indicators, can indirectly influence firm performance, underscoring the interconnected nature of oil price shocks and other economic indicators.

2.1. The impact of energy prices on macroeconomic indicators

Previous studies have thoroughly investigated the complicated channels between energy price shocks and key macroeconomic indicators, providing a valuable understanding of the complex dynamics involved. Among the channels through which energy prices impact economic growth, the exchange rate emerges as a pivotal area to explore. Notably, Lizardo and Molli (2010) demonstrated that raising energy prices depreciates a country's exchange rate, particularly in energy-importing countries. Classical economic models, as explained by Kavoussi (1984), suggested that exchange rate depreciations might increase the economic output under specific situations. However, Wang et al. (2022) highlighted the possible adverse effects of currency depreciations brought on by increased energy prices, including inflationary pressures and increasing foreign debt.

Focusing on real interest rates, another essential channel, reveals a complex relationship between energy costs and economic expansion. For instance, Milani (2009) demonstrated a clear relationship between energy prices and inflation rates. This connection, sometimes called the inflationary impact, is crucial in determining how real interest rate movements are shaped. Rafiq et al. (2016) found a positive effect of energy prices on the demand for money, which leads to a potential uptick in nominal interest rates. Consequently, this issue increases the real interest rate, affecting economic expansion, i.e., the interest rate effect.

Unemployment is another pathway through which energy prices impact economic growth. Cai et al. (2022) investigated how rising energy prices cause inflation, affecting real wages and employment levels. These studies have brought attention to the problems caused by rising energy prices, such as layoffs, lower labor productivity, and the restructuring of energy-dependent industries. Such dynamics significantly influence long-term aggregate supply, poverty rates, and overall purchasing power, highlighting the complex relationship between energy prices and economic growth through the unemployment channel. Furthermore, government consumption, which is affected by energy prices, influences economic growth. For instance, Narayan et al. (2014) highlighted the correlation between energy costs and government expenditure patterns.

The adverse effect of energy price fluctuations on investments is another channel through which changes in energy price affect economic development. Ilyas et al. (2021) argued that higher energy costs increase production expenses, reducing investment due to inflation's impact on real savings and investment returns. Moreover, the rising inflation from high energy prices raises nominal interest rates, causing bond prices to fall and discouraging investment (Wei et al., 2023). Fluctuations in oil prices also create uncertainty, prompting firms to postpone long-term investment decisions. Based on the endogenous growth model (i.e., positive relationship between investment rate and economic growth), investment is vital for economic development as it generates positive spillover effects and encourages private-sector investment, fostering economic growth (Yoon and Ratti, 2011). Rising energy prices also curtail energy use, capital utilization, and labor supply, affecting current and future investments.

One often overlooked channel through which energy prices can influence economic growth is stock prices. Energy prices can directly affect stock prices by influencing future cash flows or indirectly by impacting the interest rates used to discount these future cash flows. For instance, when oil prices increase, there is an expected decrease in earnings, which can promptly lead to a drop in stock prices if the stock market accurately accounts for the cash flow consequences of higher oil prices. High energy prices also result in higher interest rates, reducing net profits and the demand for bank loans which, in turn, leave consumers with less money to spend on goods or stocks, causing stock prices to decrease (Cunado and Perez de Gracia, 2014).

Moreover, increases in energy prices reduce the consumers' purchasing power, decreasing demand, sales, and corporate earnings, which can negatively affect businesses and stock prices. Similarly, higher energy prices increase production costs for companies, potentially lowering profits and dividends, which are key factors influencing stock prices (Gupta, 2016; Sadorsky, 1999; Yun and Yoon, 2019). The frequent fluctuations in energy prices add uncertainty, which can also adversely affect stock prices, suggesting that energy prices negatively affect stock prices. However, there is also the possibility of a positive relationship between energy prices and stock prices. Unexpected increases in energy prices can lead to unexpected inflation, raising the equity value of firms if they are net debtors.

2.2. The impact of energy prices on firm performance

Energy shocks possess the capacity to directly affect the performance of firms. Some studies have focused explicitly on the impact of oil prices on firm-level efficiency, investment, and risk. A stream of literature has examined how oil prices impact firm-level accounting measures of efficiency. For instance, Dayanandan and Donker (2011) investigated the relationship between crude oil prices and firm performance in North America from 1990 to 2008. The results indicate a positive and significant relationship between crude oil prices and firm performance, as assessed by accounting measures. Yun and Yoon (2019) investigated the impact of oil prices on firm volatility within the airline industry context. Their results demonstrate that oil prices have an impact from three perspectives, including cash flow effects. The study also reveals that oil price shocks have the potential to trigger price run-ups that may result in inflation. If the central bank responds to such inflationary pressures by raising interest rates, this action may increase the discount rate, which, in turn, could adversely affect the firms' stock market prices (Saif-Alyousfi et al., 2021).

Valadkhani (2014) argued that oil price shocks have been observed to elicit spillover effects on commodity prices, resulting in a subsequent reduction in market demand and, ultimately, a decrease in firm production scale. Lee and Lee (2019) conducted a study investigating the influence of fluctuations in oil prices on the operational efficacy of Chinese banks from 2000 to 2014. The findings show that rising oil prices significantly and negatively affect banking performance regarding earnings, liquidity, capitalization, and management effectiveness.

Fluctuations in oil prices pose a significant challenge to firms by introducing an element of unpredictability, which could impede their input costs, cash flow, profitability, valuation, investment, and overall corporate payout (Yun and Yoon, 2019). The potential effects may be subject to the influence of various demand and supply-related factors that were not directly observed. Moreover, the degree of impact exerted by distinct oil shocks may be contingent upon their underlying characteristics, as posited by Cunado and Perez de Gracia (2014) and Wang and Liao (2022).

Another stream of literature considers the relationship between oil market uncertainty and firm-level investment (Chen et al., 2020; Ilyas et al., 2021; Phan et al., 2019; Yin and Lu, 2022). For instance, Maghyereh and Abdoh (2021) discovered that oil price shocks have a negative and asymmetric effect on corporate investment in the energy sector. Ilyas et al. (2021) built on their work and showed that oil price shocks combined with uncertain economic policies impact the investment decisions of corporations, especially in countries that produce oil. Yin and Lu (2022) explored how the risk-taking behavior of Chinese firms is affected by the uncertainty surrounding oil prices. The authors discovered that a surge in oil prices leads to increased risk-taking among firms through risk compensation or the exploration of real options related to growth opportunities. In a comprehensive study, Phan et al. (2019) used a global dataset to discover the negative impact of oil price uncertainty on corporate investment. More importantly, their research underscores that this impact is intricately related to the market and stock characteristics of the firms. Chen et al. (2020) also decomposed oil shocks into supply, specific demand, and aggregate demand shocks. Their findings suggest that oil supply shocks show a positive impact, while specific demand and aggregate demand shocks negatively affect corporate investments.

In contrast to the substantial body of research examining the relationship between oil price uncertainty and firm performance or firm-level investment, little attention has been paid to investigating the impact of oil prices on firm distress risk. This lack of concentration is especially noticeable in the neglect of exploring the effects of different oil shock types. A few studies have examined the impact of energy price uncertainty on credit risk exposure (Figlewski et al., 2012; Pesaran et al., 2006). For instance, Boyd et al. (2001) posited that increasing energy prices can increase inflationary pressure, which may result in credit market frictions adversely impacting businesses. Khoja et al. (2019) pointed out that a range of dynamic scenarios can lead to financial distress in firms, and that a complete understanding of these dynamics requires considering both industry-specific characteristics and broader macroeconomic indicators, such as inflation, interest rates, and oil prices.

These studies suggest that energy shocks, particularly those related to oil prices, can significantly affect a firm's financial health, especially in energy-intensive industries with high levels of debt or leverage, and in firms that are less diversified. The severity of this impact may also depend on the nature of the shock. Consequently, the discussion above leads to the formulation of our first hypothesis, which states.

Hypothesis 1a. Energy shocks increase a firm's distress risk.

Hypothesis 1b. The impact of energy shocks on a firm's distress risk is expected to differ between firms in developed countries and those in emerging economies.

2.3. Energy diversification and distress risk

Country-level energy diversity refers to a wide range of energy sources and supply channels within a nation, including fossil fuels, renewables, and nuclear energy. This diversity compels countries to use various combinations to meet their diverse energy demands. Consequently, country-level energy diversity serves as a shock absorber, allowing governments to tap into various sources during supply disruptions. It also positions them to shift to alternative imports or energy sources from different regions, enhancing their resilience (Gozgor and Paramati, 2022).

Gupta (2016) investigated the relationship between the shocks of petroleum prices, various country-level variables, competitiveness, and oil and gas equity returns using monthly firm-level data from seventy countries. The findings indicate that macroeconomic stress detrimentally affects firms' returns, while petroleum price shocks exhibit a beneficial impact. Firms operating in countries with abundant petroleum reserves are more susceptible to market pressures and price fluctuations than those in nations with lower petroleum production levels. Moreover, petroleum firms experiencing lower competition demonstrate reduced vulnerability to price changes. On this note, country-level energy diversity moderates the association between energy shocks and a firm's default risk.

We argue that firms operating in countries with high energy diversity become less vulnerable to extreme and sudden energy price shocks. In addition, country-level diversity increases resilience to volatility, as high energy diversification permits operating firms to quickly adapt to market conditions, reducing their reliance on a single energy supply. Such firms are more likely positioned to manage their costs, service financial obligations, and sustain profitability, leading to lower distress risk. Put differently, such firms are less likely to experience severe financial default or distress because of the diverse energy factors. The discussion above leads to the formulation of the second hypothesis, which states.

Hypothesis 2a. A higher country-level energy diversity mitigates the increasing impact of energy shocks on a firm's distress risk.

Hypothesis 2b. The mitigating impact of energy diversity on the relationship between energy shocks and a firm's distress risk is expected to differ between firms in developed countries and those in emerging economies.

3. Methodology

The econometric framework of this study consists of several distinct methods. Initially, we used Merton's (1974) credit risk model to estimate the DD of firms within the sample. In the second step, we employed the SVAR approach introduced by Kilian (2009) to decompose oil price changes into supply, aggregate demand, and specific demand shocks. In the third step, we utilized the approach developed by Gozgor and Paramati (2022) to measure the Energy Diversification Index. Finally, several multifactor regression models were used to estimate the impact of oil price shocks on firms' distress risk.

3.1. Measuring oil price shocks

To measure oil price shock, we followed Kilian's (2009) analytical approach, which breaks down the real price of crude oil into three components: (1) Supply Shocks (SS), referring to variations in the current physical production of crude oil, (2) Aggregate Demand Shocks (ADS) driven by fluctuations in global economic activity, and (3) Specific (Cautionary) Demand Shocks (SDS) arising from uncertainty about whether the expected supply will be sufficient compared to the expected demand (Kilian, 2009).

We used the SVAR to construct the oil shocks, using data from several sources, including global crude oil production (obtained from the Energy Information Administration (EIA) website), the index of actual economic activity (obtained from Kilian's website), and oil price data (obtained from the EIA website).

This SVAR can be shown as follows:

$$A_0 X_t = \alpha_0 + \sum\nolimits_{i=1}^{P} A_i X_{t-i} + \varepsilon_t \tag{1}$$

In Eq. (1), X_t is a 3×1 vector of endogenous variables consisting of three components: $\Delta prod_t$, which represents the percentage change in global crude oil production, rea_t, denoting the index of real economic activity, and rop_t, referring to real oil prices. α_0 is a 3×1 vector of constant terms, while A_0 stands for a 3×3 contemporaneous matrix. ε_t is a 3×1 vector representing structural disturbance. p denotes the lag order of X_t and is chosen to be 24, following Kilian (2009). To derive the reduced-form error term, represented as δ_t, we multiplied both sides of Eq. (1) by A_0^{-1}.

$$X_t = \beta_0 + \sum\nolimits_{i=1}^{24} B_i X_{t-i} + \delta_t \tag{2}$$

In Eq. (2), $\delta_t = A_0^{-1}\varepsilon_t$, based on the work of Kilian (2009), the defined constraints in A_0^{-1} assume that there is no immediate response of oil production (supply) to changes in oil demand during the same period. Furthermore, due to the sluggish nature of adjustments in global real economic activity, it is presumed that global economic activity will not promptly react to specific oil demand shocks. Lastly, it is assumed that real oil prices will react to variations in oil production and global real economic activity within the same period. Based on these premises, δ_t is described as follows:

$$\delta_t = \left(\delta_t^{\Delta prod}\, \delta_t^{rep}\, \delta_t^{rop}\right) = \begin{pmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{SS} \\ \varepsilon_t^{ADS} \\ \varepsilon_t^{SDS} \end{pmatrix} \tag{3}$$

In Eq. (3), ε_t^{SS}, ε_t^{ADS} and ε_t^{SDS} refer to oil supply, aggregate, and oil-specific demand shocks. In addition, we followed Kilian's (2009) suggested approach to produce the annual data for three oil shocks to align with our yearly firm-level dataset.

$$\widehat{\sigma}_t = \frac{1}{12}\sum_{i=1}^{12} \widehat{\varepsilon}_{it} \tag{4}$$

where $\widehat{\sigma}_t$ and $\widehat{\varepsilon}_{it}$ refer to the annual and monthly data of each oil shock, respectively.

Fig. 1 shows the three components of the West Texas Intermediate (WTI) oil price volatility alongside the year-end closing prices from 2002 to 2022. Noteworthy is that the three oil price shocks do not follow the same pattern over the years.

In addition, for further robustness tests, we used other measures of oil price uncertainty found in the literature, including the

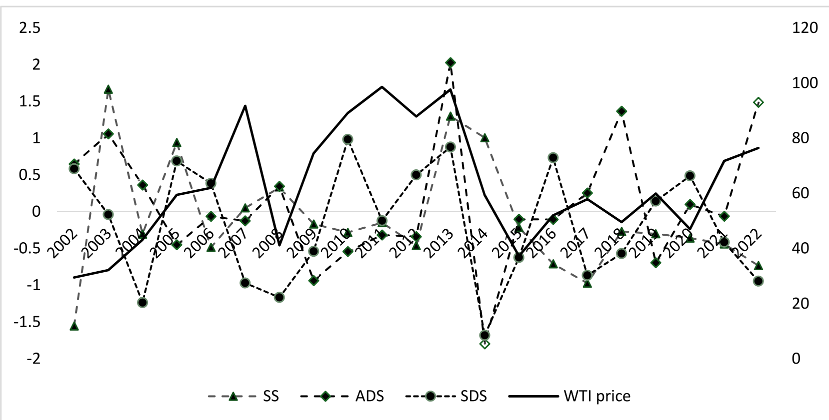

Fig. 1. WTI Crude Oil Price Shocks. Notes: The figure represents three oil price shocks: supply shocks (*SS*), aggregate demand shocks (*ADS*), and oil-specific demand shocks (*SDS*), all estimated using the SVAR approach by Kilian (2009).

Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model (Sadorsky, 2006; Wang et al., 2017) and the Standard Deviation (SD) of daily returns of oil price, which will then converted to an annual basis (Henriques and Sadorsky, 2011; Phan et al., 2019; Sadorsky, 2006).

3.2. Measuring firm-level distress risk

We used the distance to default measure, introduced by Merton (1974), to measure firm-level distress risk. This measure is recognized for predicting firm-level distress risk in academic and industry research (Andreou et al., 2021; Bharath and Shumway, 2008; Nguyen et al., 2023).

We also computed the firms' probability of default using the "naive" Merton DD model as described by Bharath and Shumway (2008). In this model, the inputs are either observable from the company's financial reports or can be inferred from stock-based data. According to option pricing theory, the model posits that a company's equity value can be associated with the value of a call option based on its asset value. It further argues that a firm faces bankruptcy if the overall value of its assets falls below its debt value.

Thus, the following model, represented in Eq. (5), establishes a standardized measure to indicate the distance between the estimated asset value and the debt level. Eq. (5) displays the firm's DD, denoted as DD_{it}, for firm i at year t, projected over a T-year period into the future:

$$DD_{i,t} = \frac{\ln\left(\frac{V_A}{X}\right) + \left(\mu_{t-1} - 0.5\sigma_A^2\right).T}{\sigma_A\sqrt{T}} \tag{5}$$

where V_A is the total asset value for firm i in year t, which is the combination of the firm's market value of equity (V_E) and the firm's book value of debt (X) in year t; μ_{t-1} is the expected return for firm i measured in year $t-1$ proxied by the previous year's cumulative monthly stock returns; σ_A represents the volatility of the firm's total assets, which is calculated as the weighted average of the volatility of debt (σ_D) and equity (σ_E).

Distress risk (DR) is the likelihood that a firm i experiences financial distress at a specific time t. This likelihood is calculated as the cumulative standard normal distribution of the negative DD, hence:

$$DR_{i,t} = N\left(-DD_{i,t}\right) \tag{6}$$

Fig. 2 presents the firms' DR over time across various subsamples, categorized by geographic region, development status, whether

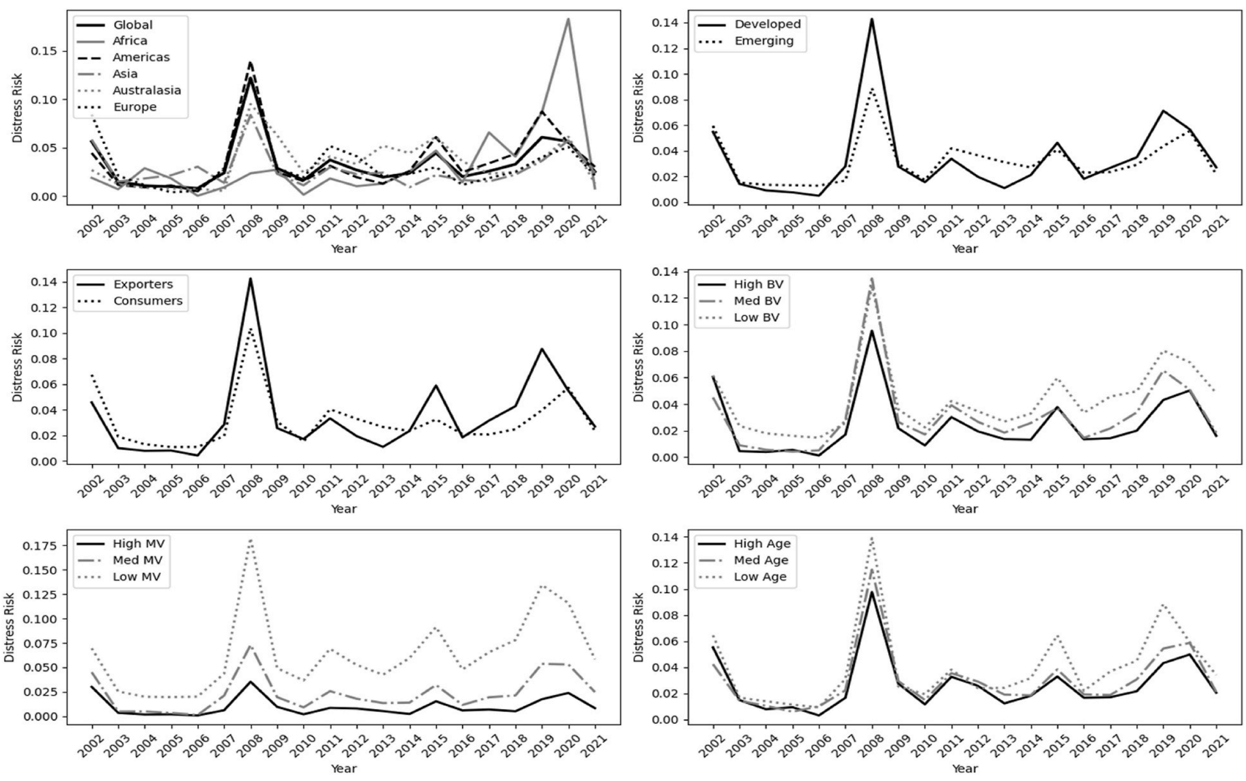

Fig. 2. Distress risk analysis across regions and firm characteristics.

they are a producer of oil or a consumer of oil, and vital firm characteristics such as market value (MV), book value (BV), and age. Globally, DR increased during the Global 2008 Financial Crisis and the COVID-19 outbreak. Developed markets experienced greater DR volatility than emerging markets, particularly during the 2008 financial crisis. Increases in DR are greater for oil producers than consumers, indicating that they are more susceptible to global economic downturns. Firms with lower BV and MV tend to be more financially vulnerable, showing a persistent higher DR during financial recessions. Younger firms also show higher DR, especially during economic recessions. The graphs indicate that distress risk is strongly associated with firm size, age, and market role, especially during a financial crisis.

3.3. Measuring energy diversification

The Energy Diversification Index (EDI) proposed by Gozgor and Paramati (2022) was used. This index measures the diversity of energy consumption across countries. EDI can be defined as:

$$EDI_{kt} = \frac{\sum_{k=1}^{n_i} \left(\frac{x_{kt}}{X_{kt}}\right)^2 - \frac{1}{n_i}}{1 - \frac{1}{n_i}} \tag{7}$$

In Eq. (7), X_{kt} is the overall energy consumption for country k, x_{kt} is the energy consumption from different sources (coal, hydroelectric, natural gas, nuclear, oil, and renewables) and n_i is the number of energy sources (n = 6), k represents the country, and t denotes the year. Greater EDI values indicate more of an energy concentration (less energy diversification). The related data on EDI was obtained from Gozgor and Paramati (2022).

3.4. Estimated empirical models

This study employed a panel regression model to analyze the impact of three oil shocks on firm distress risk, as outlined below.

$$DR_{it} = \beta_0 + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \sum_{j=1}^{J} \beta_j \, controls_{t-1,j} + \varepsilon_{it} \tag{8}$$

In Eq. (8), DR_{it} refers to the default risk of firm i in year t. Oil supply shocks, aggregate demand shocks, and specific supply shocks are each denoted by S_t , ADS_t, and SDS_t in year t, respectively.

In addition, we followed the literature (Bharath and Shumway, 2008; Brogaard et al., 2017; Islam et al., 2022; Shumway, 2001) in controlling for some of the firm-level variables, including Net Income to Total Assets (NITA), Total Liabilities to Total Assets (TLTA), Excess Return (EXRET), Stock Return Volatility (Sig E), Book to Market Value (BM), Cash to Total Asset (CashTA), and size, as well as gross domestic product (GDP) growth rate at the country level. Distress risk was assessed simultaneously, and the firm-level control variables were shifted to a one-period lag. This choice was informed by two key considerations. Firstly, a firm's financial performance in the most recent year, as shown in its financial statements, significantly affects its current creditworthiness and financial health. Secondly, using firm-level control variables from year t-1 helps to mitigate concerns related to endogeneity.

At this stage, we model the moderating impact of energy diversifications on the nexus between oil shocks and a firm's *DR* using the following regression:

$$DR_{it} = \alpha + \beta_1 SS_t + \beta_2 \, ADS_t + \beta_3 SDS_t + \beta_4 EDI_{kt} \times SDS_t + \sum_{j=1}^{J} \beta_j \, controls_{t-1,j} + \varepsilon_{it} \tag{9}$$

In Eq. (9), EDI_{kt} refers to the Energy Diversification Index for country k at year t. Other variables are defined in Eq. (8).

3.5. Data sources

We used two sets of data for our analysis: firm-specific data and crude oil price data. As discussed in the methodology, we measured the firms' distress risk as our econometric framework's primary variable of interest. In addition, we followed the literature to control some of the firm-level and country-level variables. All data relating to individual firms were collected from Refinitiv. Detailed information regarding each of these variables can be found in Table 1. Data were gathered annually from 2002 to 2022. We employed a commonly applied data filtering procedure, which involved the following steps: (1) removing financial and utility stocks, (2) retaining only stocks with complete data for all variables, and (3) applying winsorization to limit extreme values at the 1st and 99th percentiles

Table 1
Variables' Definitions.

Variable	Description	Source
Default Risk (*DR*)	Calculated as the cumulative standard normal distribution of the negative Distance to Default (*DD*), as measured by the Merton (1974) model	Authors' calculation following Merton (1974)
Supply Shock (*SS*)	Oil supply shock derived from the SVAR model of Kilian (2009)	Authors' calculation following Kilian (2009)
Aggregate Demand Shock (*ADS*)	Aggregate demand shock derived from the SVAR model of Kilian (2009)	Authors' calculation following Kilian (2009)
Specific Demand Shock (*SDS*)	Specific demand shock derived from the SVAR model of Kilian (2009)	Authors' calculation following Kilian (2009)
Net Income Scaled by Total Assets (*NITA*)	Calculated as net income scaled by total assets	Refinitiv
Total Liabilities Scaled by Total Assets (*TLTA*)	Calculated as total liabilities scaled by total assets	Refinitiv
Annual Stock Returns (*ExRet*)	Cumulative annual return for year *t* minus the value-weighted stock index return in year *t*	Authors' calculation
Standard Deviation of Stock Returns (*SigE*)	Calculated as the standard deviation of the residuals derived from regressing monthly stock returns on market returns for year *t*	Authors' calculation
Book Market Value (*BM*)	Calculated as the ratio of the book value of equity to market value of equity	Refinitiv
Cash to Total Assets (*CashTA*)	Calculated as the ratio of cash to total assets	Refinitiv
Firm Size (*Size*)	Calculated as the natural logarithm of total assets	Refinitiv
Corporate Social Responsibility (*CSR*)	Calculated as the arithmetic average of environmental score and social score	Refinitiv
Gross Domestic Product (*GDP*)	GDP growth rate	World Development Indicators, World Bank
Consumer Price Index (CPI)	Consumer price index of the United States	Federal Reserve Bank of St. Louis
Spot oil price	WTI monthly spot oil price	Energy Information Association
Energy Diversification Index (*EDI*)	Measures the diversity of energy consumption across countries	Authors' calculation
Number of Employees	Represents the total number of part-time and full-time employees of each firm	Refinitiv
KZ Index	A measure the severity of a firm's financial constraints, as developed by Kaplan and Zingales (1997)	Authors' calculation following Lamont et al. (2001)
Managerial Ability	Measured by Demerjian et al. (2012) based on a manager's ability to generate revenues.	Demerjian's database

to mitigate the impact of outliers.[1] As a result of these filtering steps, we were left with a dataset comprising 8130 companies from 48 countries,[2] including a total of 80,151 firm-year observations. Additionally, we collected country-level data concerning firms, which involved metrics such as the GDP sourced from the World Bank and energy diversity from Gozgor and Paramati (2022).

We followed Phan et al. (2019) in grouping 8130 firms into different panels based on their location and stock attributes. First, we created panels representing the aggregated markets, including a global (comprising all stocks in our sample) panel, a developed country panel, an emerging country panel, and five continent-specific panels. Additionally, we constructed several panels based on stock attributes, including stock Book Value (BV), Market Value (MV) and age.

Regarding oil price shocks, following Chen et al. (2020) and Su et al. (2018), WTI oil spot prices were selected as the proxy for global oil prices. The monthly crude oil price data were collected from the EIA website. The monthly data of real global economic activity can be accessed on Lutz Kilian's website. In contrast, the United States Consumer Price Index (CPI), utilized for computing real oil prices, was sourced from the Federal Reserve Bank of St. Louis website. Following Kilian (2009), in conjunction with the SVAR model, these datasets enable the extraction of oil supply shocks, aggregate shocks, and oil-specific demand shocks. These shocks were derived separately using the WTI spot price data. We used Eq. (4) to obtain the annual oil shocks.

Table 2 presents the summary statistics of the main variables in our study for the different aggregate market panels (i.e., global, developed, emerging, five continent-based, oil-producer, and oil-consumer panels) and nine firm-characterized panels based on book value, market value, and the age of the firms.

In addition, Table 3 presents the summary statistics of the oil price shocks used in this study.

4. Empirical results

The findings are presented in different subsections. First, we offer evidence of the impact of crude oil price shocks on corporate distress risk using preliminary and panel data regression analysis. Next, we demonstrate the findings on the moderating effect of energy

[1] This data filtering procedure has been used in other corporate performance and risk papers, such as Mousavi et al. (2019) and Phan et al. (2019).

[2] Argentina, Australia, Austria, Belgium, Brazil, Canada, China, Denmark, Finland, France, Germany, Greece, Hungry, India, Ireland, Israel, Italy, Japan, Kazakhstan, Luxembourg, Malaysia, Mexico, Morocco, the Netherlands, New Zealand, Oman, Pakistan, Peru, the Philippines, Poland, Portugal, Qatar, Romania, Russia, Saudi Arabia, Singapore, Slovenia, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Turkiye, the United Arab Emirates, the United Kingdom, the United States, and Vietnam.

Table 2
Summary statistics of the panel data.

Panel	No. of firms	DR		NITA		TLTA		EXRET		Sig E		BM		CashTA		Size		EDI	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Panel A: Aggregate Market Panels																			
Global	82,924	0.033	0.140	0.023	0.178	0.540	0.259	−0.021	0.430	0.366	0.225	0.633	1.878	0.073	0.142	7.414	1.837	6.967	2.661
Developed	51,396	0.034	0.143	0.011	0.192	0.546	0.283	−0.046	0.440	0.372	0.234	0.603	1.262	0.067	0.156	7.407	1.877	7.902	1.251
Emerging	31,528	0.032	0.136	0.044	0.150	0.530	0.213	0.018	0.411	0.357	0.210	0.682	2.585	0.084	0.116	7.424	1.771	5.443	3.511
Americas	38,760	0.036	0.146	0.004	0.196	0.538	0.298	−0.059	0.464	0.392	0.244	0.583	2.323	0.063	0.168	7.263	1.817	7.988	1.173
Europe	23,826	0.032	0.140	0.036	0.161	0.579	0.216	0.016	0.396	0.331	0.199	0.705	1.629	0.083	0.119	7.596	1.853	7.393	3.446
Australasia	5103	0.035	0.143	−0.001	0.266	0.441	0.213	−0.013	0.502	0.402	0.275	0.730	0.925	0.065	0.154	6.276	1.927	6.186	1.438
Africa	1465	0.031	0.139	0.074	0.099	0.539	0.174	0.005	0.389	0.315	0.170	0.676	0.842	0.087	0.092	6.979	1.332	2.097	0.122
Asia	13,770	0.027	0.120	0.061	0.085	0.514	0.212	0.015	0.346	0.348	0.182	0.611	1.024	0.087	0.087	7.990	1.605	4.164	1.899
Oil Producer	37,769	0.036	0.147	0.002	0.199	0.536	0.301	−0.067	0.464	0.391	0.245	0.557	0.864	0.062	0.170	7.260	1.841	7.939	1.385
Oil Consumer	45,155	0.031	0.134	0.042	0.156	0.543	0.218	0.017	0.396	0.345	0.205	0.697	2.418	0.083	0.113	7.542	1.824	6.154	3.155
Panel B: Firm-characterized Panels																			
High MV	28,495	0.010	0.069	0.060	0.081	0.577	0.205	0.007	0.312	0.289	0.152	0.442	0.363	0.102	0.085	9.078	1.263	6.795	2.569
Med MV	27,272	0.024	0.113	0.040	0.116	0.540	0.224	0.000	0.386	0.349	0.190	0.571	0.498	0.084	0.107	7.402	0.987	6.925	2.755
Low MV	27,157	0.066	0.201	−0.031	0.268	0.501	0.327	−0.073	0.557	0.464	0.280	0.897	3.205	0.032	0.200	5.679	1.317	7.189	2.645
High BV	28,549	0.025	0.118	0.047	0.058	0.560	0.178	−0.033	0.322	0.294	0.162	0.730	2.912	0.088	0.062	9.229	1.108	6.835	2.641
Med BV	27,178	0.031	0.135	0.044	0.088	0.525	0.196	−0.018	0.397	0.354	0.197	0.633	0.959	0.088	0.085	7.363	0.669	6.938	2.722
Low BV	27,197	0.043	0.164	−0.023	0.287	0.533	0.363	−0.013	0.546	0.454	0.274	0.531	0.960	0.043	0.222	5.558	1.284	7.134	2.611
High Age	28,977	0.027	0.126	0.046	0.130	0.552	0.210	−0.011	0.368	0.322	0.184	0.680	2.708	0.088	0.086	7.816	1.739	6.897	2.624
Med Age	25,947	0.032	0.136	0.024	0.188	0.531	0.260	−0.020	0.429	0.375	0.223	0.586	1.227	0.074	0.150	7.296	1.833	6.795	2.741
Low Age	28,000	0.040	0.156	0.000	0.206	0.535	0.299	−0.033	0.488	0.404	0.256	0.629	1.210	0.058	0.176	7.106	1.866	7.198	2.608

Notes: The table presents the number of firm-year observations, along with the average and standard deviation values of the main variables, for different aggregate market panels (i.e., global, developed, emerging, five continent-based, oil-producer, and oil-consumer panels) as well as nine firm-characterized panels.

Table 3
Summary statistics of oil price Volatilities from 2002 to 2021.

Year	SS	SDS	ADS	GARCH (1,1)	σ_{oil}
2002	0.086	−0.002	−0.152	0.062	0.004
2003	0.120	−0.211	0.422	0.083	0.006
2004	0.190	−0.116	0.350	0.062	0.003
2005	−0.042	0.149	0.070	0.072	0.005
2006	−0.118	−0.014	0.358	0.065	0.003
2007	−0.191	0.054	0.352	0.062	0.003
2008	−0.199	−0.382	−0.373	0.074	0.018
2009	0.210	−0.001	0.304	0.097	0.005
2010	0.162	0.066	−0.285	0.057	0.002
2011	−0.032	0.493	0.007	0.050	0.002
2012	−0.014	0.288	−0.383	0.052	0.002
2013	−0.107	0.182	0.311	0.040	0.000
2014	0.250	−0.016	−0.037	0.045	0.004
2015	0.320	−0.434	−0.237	0.087	0.008
2016	0.064	0.054	0.193	0.074	0.007
2017	−0.207	0.080	0.078	0.068	0.003
2018	−0.028	−0.069	−0.015	0.053	0.004
2019	−0.158	0.050	0.199	0.069	0.003
2020	−0.963	−0.478	−0.373	0.132	0.031
2021	0.337	0.089	−0.037	0.085	0.009
Mean	−0.016	−0.011	0.038	0.069	0.006
Median	−0.021	0.024	0.038	0.067	0.004
Std.	0.274	0.227	0.264	0.020	0.007
Min.	−0.963	−0.478	−0.383	0.040	0.000
Max.	0.337	0.493	0.422	0.132	0.031

Note: The table presents descriptive statistics for the volatility variables of WTI oil prices.

diversification on the impact of energy shocks on distress risk. Furthermore, we present various robustness tests in connection to the baseline results.

4.1. Impact of oil shocks on firms' distress risk

Table 4 reports on the univariate analysis used to capture the firms' *DR* in periods characterized by low and high crude oil price uncertainty. The average values of a firms' *DR* during years marked as low and high uncertainty, the difference between the firm's *DR*

Table 4
Univariate analyses.

Panel	Low Uncertainty	High Uncertainty	Difference	t-statistics	p-value
Panel A: Aggregate Market Panels					
Global	0.025	0.040	−0.016	−16.06	0.000
Developed	0.023	0.043	−0.020	−16.10	0.000
Emerging	0.027	0.035	−0.008	−5.268	0.000
Americas	0.023	0.048	−0.025	−16.81	0.000
Europe	0.029	0.034	−0.005	−2.597	0.009
Australasia	0.027	0.042	−0.015	−3.848	0.000
Africa	0.015	0.047	−0.032	−4.450	0.000
Asia	0.022	0.030	−0.009	−4.240	0.000
Oil Producer	0.024	0.047	−0.023	−15.45	0.000
Oil Consumer	0.025	0.035	−0.009	−7.441	0.000
Panel B: Firm-characterized Panels					
High BV	0.017	0.031	−0.014	−9.696	0.000
Med BV	0.024	0.038	−0.014	−8.570	0.000
Low BV	0.032	0.053	−0.021	−10.65	0.000
High MV	0.006	0.013	−0.007	−8.817	0.000
Med MV	0.017	0.031	−0.014	−10.22	0.000
Low MV	0.050	0.082	−0.032	−13.26	0.000
High Age	0.020	0.033	−0.013	−8.510	0.000
Med Age	0.024	0.038	−0.015	−8.588	0.000
Low Age	0.030	0.051	−0.022	−11.60	0.000

Notes: The table presents the average distress risk (DR) of firms during periods of elevated uncertainty in crude oil prices compared to periods of low uncertainty. High crude oil price uncertainty refers to years in which *OILVOL* exceeds its median value over the sample period; otherwise, it signifies low uncertainty. The table also includes the *DD* gap between low and high uncertainty years, along with the corresponding *t*-statistics and *p*-values, testing the null hypothesis that this gap equals zero.

in periods of high and low crude oil price uncertainty, along with the corresponding t-statistics and p-values, are also reported. A year with high uncertainty is defined as one when oil price volatility, calculated using the GARCH (1,1) model, exceeds the median value observed across the entire sample period; otherwise, it indicates low uncertainty.

All panels show a higher distress risk or probability of default during years of high oil price uncertainty than low oil price uncertainty. For example, in the global panel of all firms, years with high crude oil price uncertainty show a *DR* that is 1.6% greater than in years with low oil price uncertainty. The *DR* is higher in firms in developed countries (2.0%) compared to firms in emerging economies (0.8%). This evidence is consistent with our expectation of seeing a significant difference between the firms in developed and emerging economies. Similar evidence is observed regarding the regional markets. For instance, firms in America have a *DR* of 2.5%, which is significantly higher than the firms in Europe (0.5%), Asia (0.9%), and Australasia (1.5%). In addition, African firms have the largest *DR* with a value of 3.2%. Finally, the firms' *DR* is higher in oil producer nations (2.3%) compared to oil consumer nations (0.9%) globally.

In the firm-characteristic panels, the firms' *DR* is significantly higher during periods of high oil price uncertainty, especially for those with varying Market Value (*MV*) and Book Value (*BV*). The gap is wider for firms with low BV, MV, and age. The statistical proof across all firm panels suggests a positive impact due to crude oil price uncertainty on the firms' distress risk.

Table 5 presents the regression results to estimate the impact of crude oil shocks on the firms' *DR*. Model 1 suggests that the coefficients of oil Supply Shock (*SS*), oil Specific Demand Shock (*SDS*), and oil Aggregate Demand Shock (*ADS*) are −0.072, 0.115 and 0.029, respectively. These coefficients are significant at the 1% ($p < 0.01$). Therefore, the firms' *DR* is negatively influenced by oil *SS*

Table 5
The panel regression results.

Variable	Baseline Model	Model 1	Model 2	Model 3
SS		−0.072***	−0.070***	−0.113***
		(0.005)	(0.005)	(0.010)
SDS		0.115***	0.115***	0.143***
		(0.009)	(0.009)	(0.012)
ADS		0.029***	0.028***	0.032***
		(0.005)	(0.005)	(0.008)
$log(ED_{t-1})$			−0.003**	−0.003*
			(0.002)	(0.002)
$SS \times log(ED_{t-1})$				0.022***
				(0.004)
$SDS \times log(ED_{t-1})$				−0.015***
				(0.005)
$ADS \times log(ED_{t-1})$				−0.002
				(0.003)
$NITA_{t-1}$	0.002	0.002	0.001	0.002
	(0.008)	(0.008)	(0.008)	(0.008)
$TLTA_{t-1}$	0.077***	0.077***	0.078***	0.078***
	(0.009)	(0.009)	(0.009)	(0.009)
$EXRET_{t-1}$	−0.048***	−0.048***	−0.049***	−0.049***
	(0.002)	(0.002)	(0.002)	(0.002)
$sigE_{t-1}$	0.099***	0.099***	0.099***	0.099***
	(0.005)	(0.005)	(0.005)	(0.005)
BM_{t-1}	0.005*	0.005*	0.005*	0.005*
	(0.003)	(0.003)	(0.003)	(0.003)
$CashTA_{t-1}$	0.004	0.004	0.004	0.004
	(0.011)	(0.011)	(0.011)	(0.011)
$Size_{t-1}$	0.002***	0.002***	0.002***	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)
GDP_{t-1}	−0.052***	−0.052***	−0.058***	−0.057***
	(0.010)	(0.010)	(0.010)	(0.010)
Constant Term	−0.076***	−0.055***	−0.048***	−0.050***
	(0.006)	(0.005)	(0.006)	(0.006)
Observations	79,195	79,195	79,195	79,195
R-squared	0.119	0.119	0.119	0.119
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes

Notes: The table displays the regression results indicating the impact of crude oil price shocks on distress risk across the global panel. *SS*, *ADS*, and *SDS* represent oil supply shocks, aggregate demand shocks, and oil-specific demand shocks. The baseline model includes control variables. Model 1 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \sum \beta_5 controls + \varepsilon_{it}$) tests Hypothesis 1a. Model 2 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 SDS_t + \beta_3 ADS_t + \beta_4 \times \log(ED_{t-1}) + \sum_{j=1}^{J} \beta_j\, controls_{tj} + \varepsilon_{it}$) examines the direct impact of energy diversity on distress risk. Model 3 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \beta_4 \log(ED_{t-1}) + \beta_5 \log(ED_{t-1}) \times SS_t + \beta_6 \log(ED_{t-1}) \times SDS_t + \beta_7 \log(ED_{t-1}) \times ADS_t + \sum_{j=1}^{J} \beta_j\, controls_{tj} + \varepsilon_{it}$) tests Hypothesis 2a, examining the moderating impact of energy diversification on *SDS*, as well as its moderating impact on two other sources of oil shocks, namely *ADS* and *SS*. Robust standard errors are reported. ***$p < 0.01$, **$p < 0.05$, and * $p < 0.10$.

but positively impacted by both oil *SDS* and *ADS*. The results for Models 2 and 3 are in line with the results of Model 1. All of these results included the control variables, which were discussed earlier.

These findings imply that oil shocks originating from different sources affect distress risk in varying ways. The rise in oil prices resulting from supply shocks means a decrease in global oil production, which can lead to a lower interest rate (Kim et al., 2017). As interest rate adjustments are a macro-level phenomenon, a lower interest rate could benefit firms concerning distress risk (Bonfim, 2009; Pesaran et al., 2006) and investments (Chen et al., 2020).

Multiple explanations exist for why oil aggregate demand shocks positively affect firm distress risk. The actual global economic activity reacts concurrently to oil aggregate demand and supply shocks, per the decomposition principle of oil shocks (Kilian, 2009; Kim and Vera, 2019). This evidence indicates that oil aggregate demand shocks result from the section of real global demand activity untouched by oil supply shocks. Therefore, it can be inferred that the oil supply is flexible and that the oil aggregate demand shock adjusts with the economic demand (Chen et al., 2020). Firms might be affected by shocks due to an increase in oil prices in two ways. First, increased oil prices can potentially drive up production costs and lower profits, even when an adequate oil supply exists for their operations. Second, a decline in consumer spending brought on by an increase in oil prices might worsen the situation by lowering the demand for the firms' products. Both conditions result in an increased risk of distress. Furthermore, as Zhao et al. (2016) noted, oil aggregate demand shocks positively affect interest rates and inflation. This dual macro-level effect has adverse consequences for firms, negatively influencing investments and the overall financial health of firms.

The positive impact of a specific demand shock on a firm's distress risk can be justified for several reasons. According to the decomposition principle of oil shocks, the oil demand shocks stem from complex factors, such as unexpected oil price changes, supply chain and production process disruptions, and irregular global economic activity changes (Gozgor et al., 2023). The uncertainty surrounding oil prices could result in ambiguity in the financial environment for firms, affecting input costs and production expenses. This growing uncertainty exposes the firm to a higher distress risk.

We extended the regression to other panels. Section A of Table 6 demonstrates that the coefficient of oil *SS* is negative for all panels (ranging from −0.037 to −0.117) and is significant at the 1% level ($p < 0.01$) for most aggregate market panels and all firm characteristic panels. Notably, the oil *SS* coefficient is negative but insignificant in the Africa panel. In addition, the coefficients of oil *SDS* are positive (ranging from 0.054 to 0.202) and significant at the 1% level ($p < 0.01$) across all panels except Africa. Finally, the coefficients of oil *ADS* are positive and significant for some panels, including for the firms in Global, Developed, Emerging, Americas, and oil-producer countries at the 1% level ($p < 0.05$).

4.2. The moderating impact of energy diversification

Model 2 in Table 5 examines the direct impact of energy diversification on a firm's *DR*. The results for *SS*, *SDS,* and *ADS* align with Model 1. The coefficient of $log\,(ED)$ is −0.003 and significant ($p < 0.05$), indicating that energy diversification reduces a firm's distress risk. In addition, Model 3 presents the moderating impact of energy diversification on the relationship between the three oil shocks and a firm's *DR*. The regression results reveal that the coefficients of $SDS \times log\,(ED)$ and $SS \times log\,(ED)$ are both significant (p < 0.01), with values of −0.015 and 0.022, respectively. The coefficient of $ADS \times log\,(ED)$ is negative but not significant. Therefore, the positive impact of *SDS* on *DR* (and the negative effects of *SS* on *DR*) is mitigated (and strengthened, respectively) by higher energy diversification. All of these results included the control variables, which were discussed earlier.

Section B of Table 6 presents the extended regression results for Model 3 across various panels. The findings indicate that the moderating impact of energy diversification (log (*ED)*) on the relationship between *SDS* and the firms' *DR* is negative, ranging from −0.014 to 0.009, and that it is significant for the global, Americas, Europe, oil-producing and majority of firm-characterized panels.

This evidence implies that while energy diversification reduces the adverse impact of oil *SDS* on a firm's *DR* at the global level, its moderating implications are inconsistent across all panels. For example, although energy diversification mitigates the negative impact of oil *SDS* on *DR* in the Americas and Europe, it strengthens the negative impact in emerging countries. Notably, the moderating effect of energy diversification on a firm's *DR* for oil-producer and oil-consumer countries indicates a reverse pattern. Specifically, energy diversification benefits oil producers by reducing the negative impact of *SDS* on a firm's *DR*. At the same time, it harms consumers. These results underscore the complex and varied ways energy diversity interacts with oil *SDS* across different regions and sectors.

Furthermore, the moderating impact of energy diversification (log (*ED)*) on the relationship between *SS* and a firm's *DR* is positive, ranging from 0.013 to 0.617, and is significant for the Global, Americas, Emerging, Europe, Africa, and Consumer panels, and the majority of firm-characterized panels. Notably, while energy diversification does not mitigate the effect of *SS* on *DR* for oil-producer countries, it provides a moderation effect for oil-consumer countries.

4.3. Additional tests

Our study reports on the further analyses of the effects of oil shocks on firm distress risk. We examined whether the effect differs between the producers and consumers of crude oil at the country and industry levels, and between large and small to medium-sized firms. We also evaluated whether companies with a superior managerial ability are impacted differently than those with an inferior ability. We also investigated how this relationship varies during years of financial crisis (2007 and 2008) and the COVID-19 pandemic (2020 and 2021).

4.3.1. Oil consumer and oil producer industries and countries

We suggest that the impact of oil price shocks on the probability of default differs according to a firm's role in the oil and oil-related

Table 6
Extended regressions results of models 2 and 3 for the different panel datasets.

	Section A: Extended Regressions for Model 1				Section B: Extended Regression for Model 3								
	SS	ADS	SDS	R-squared	SS	ADS	SDS	log (*ED*)	*SS* × log (*ED*)	*SDS* × log (*ED*)	*ADS* × log (*ED*)	Observation	R-squared
Panel A: Aggregate Market Panels													
Global	−0.072***	0.029***	0.115***	0.119	−0.113***	0.032***	0.143***	−0.003*	0.022***	−0.015***	−0.002	79,195	0.119
	(0.005)	(0.005)	(0.009)		(0.010)	(0.008)	(0.012)	(0.002)	(0.004)	(0.005)	(0.003)		
Developed	−0.085***	0.037***	0.149***	0.130	−0.152***	0.014	0.198***	−0.010*	0.032**	−0.023	0.012	48,743	0.130
	(0.005)	(0.005)	(0.009)		(0.034)	(0.034)	(0.044)	(0.006)	(0.016)	(0.021)	(0.016)		
Emerging	−0.057***	0.015**	0.070***	0.122	−0.100***	0.022**	0.051***	0.000	0.024***	0.014**	−0.004	30,452	0.123
	(0.005)	(0.005)	(0.009)		(0.013)	(0.011)	(0.016)	(0.002)	(0.005)	(0.006)	(0.005)		
Americas	−0.096***	0.053***	0.198***	0.131	−0.125***	0.002	0.401***	−0.014**	0.015	−0.099***	0.025	36,962	0.132
	(0.005)	(0.005)	(0.009)		(0.034)	(0.038)	(0.049)	(0.007)	(0.016)	(0.023)	(0.018)		
Europe	−0.037***	0.005	0.059***	0.138	−0.062***	−0.016	0.094***	−0.006	0.013*	−0.089***	0.011	22,495	0.139
	(0.005)	(0.005)	(0.009)		(0.020)	(0.019)	(0.031)	(0.004)	(0.008)	(0.013)	(0.009)		
Australasia	−0.117***	0.026*	0.114***	0.172	0.008	−0.076	0.247**	−0.034***	−0.058	−0.067	0.042	5525	0.173
	(0.005)	(0.005)	(0.009)		(0.122)	(0.065)	(0.100)	(0.012)	(0.067)	(0.043)	(0.032)		
Africa	−0.212	0.021	0.098	0.216	−0.736***	0.047	0.978*	−0.295	0.617***	−1.044	0.001	1417	0.218
	(0.005)	(0.005)	(0.009)		(0.137)	(0.227)	(0.584)	(0.180)	(0.127)	(0.772)	(0.310)		
Asia	−0.057***	−0.016	0.061***	0.163	−0.077***	−0.01	0.025	0.009***	0.01	0.024**	−0.002	12,796	0.164
	(0.005)	(0.005)	(0.009)		(0.017)	(0.017)	(0.023)	(0.003)	(0.008)	(0.011)	(0.010)		
Oil Producer	−0.107***	0.058***	0.202***	0.134	−0.120***	−0.004	0.324***	−0.003	0.009	−0.062***	0.030**	36,230	0.135
	(0.005)	(0.005)	(0.009)		(0.023)	(0.025)	(0.037)	(0.004)	(0.010)	(0.017)	(0.012)		
Oil Consumer	−0.049***	0.007	0.054***	0.117	−0.091***	0.023**	0.035**	−0.002	0.023***	0.012**	−0.009**	42,965	0.118
	(0.005)	(0.005)	(0.009)		(0.012)	(0.010)	(0.014)	(0.002)	(0.005)	(0.005)	(0.004)		
Panel B: Firm-characterized Panels													
High BV	−0.072***	0.010*	0.107***	0.101	−0.119***	0.005	0.131***	−0.005***	0.026***	−0.014*	0.003	27,947	0.102
	(0.005)	(0.005)	(0.009)		(0.015)	(0.011)	(0.018)	(0.002)	(0.006)	(0.007)	(0.005)		
Med BV	−0.097***	0.051***	0.151***	0.140	−0.119***	0.035**	0.176***	−0.002	0.012*	−0.014*	0.009	26,150	0.140
	(0.005)	(0.005)	(0.009)		(0.015)	(0.014)	(0.020)	(0.002)	(0.006)	(0.007)	(0.006)		
Low BV	−0.063***	0.023**	0.116***	0.159	−0.114***	0.064***	0.157***	−0.003	0.026**	−0.021**	−0.021***	25,098	0.159
	(0.005)	(0.005)	(0.009)		(0.025)	(0.018)	(0.026)	(0.003)	(0.011)	(0.010)	(0.008)		
High MV	−0.035***	0.0000	0.042***	0.053	−0.066***	−0.009	0.044***	−0.005***	0.017***	−0.001	0.005*	27,731	0.055
	(0.005)	(0.005)	(0.009)		(0.010)	(0.007)	(0.011)	(0.001)	(0.004)	(0.004)	(0.003)		
Med MV	−0.087***	0.022***	0.123***	0.136	−0.098***	0.011	0.136***	0.001	0.006	−0.007	0.006	26,274	0.137
	(0.005)	(0.005)	(0.009)		(0.014)	(0.011)	(0.017)	(0.002)	(0.006)	(0.006)	(0.004)		
Low MV	−0.139***	0.091***	0.194***	0.208	−0.225***	0.144***	0.248***	−0.002	0.044***	−0.027**	−0.027***	25,190	0.208
	(0.005)	(0.005)	(0.009)		(0.029)	(0.023)	(0.032)	(0.004)	(0.013)	(0.012)	(0.010)		
High Age	−0.052***	0.023***	0.069***	0.110	−0.088***	0.034***	0.075***	−0.005**	0.019**	−0.002	−0.006	28,311	0.111
	(0.005)	(0.005)	(0.009)		(0.017)	(0.013)	(0.020)	(0.002)	(0.008)	(0.008)	(0.006)		
Med Age	−0.068***	0.029***	0.094***	0.129	−0.112***	0.014	0.123***	−0.005*	0.026***	−0.017**	0.008	25,679	0.13
	(0.005)	(0.005)	(0.009)		(0.016)	(0.014)	(0.020)	(0.003)	(0.007)	(0.008)	(0.006)		
Low Age	−0.105***	0.039***	0.210***	0.133	−0.134***	0.052***	0.259***	0.001	0.015*	−0.025***	−0.007	25,205	0.133
	(0.005)	(0.005)	(0.009)		(0.021)	(0.016)	(0.026)	(0.002)	(0.008)	(0.008)	(0.006)		

Notes: The table presents the extended regression results from Models 1 and 3, applied to different aggregate market panels (i.e., global, developed, emerging, five continent-based, oil-producer, and oil-consumer) and eight firm-characterized panels. *SS*, *ADS*, *SDS,* and *ED* represent oil supply shock, aggregate demand shocks, oil-specific demand shocks, and country-level energy diversity, respectively. The regression Model 1 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \sum_{j=1}^{J} \beta_j \ controls_{t-1j} + \varepsilon_{it}$) tests Hypothesis 1a. The regression Model 3 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \beta_4 \log(ED_{t-1}) + \beta_5 \log(ED_{t-1}) \times SS_t + \beta_6 \log(ED_{t-1}) \times SDS_t + \beta_7 \log(ED_{t-1}) \times ADS_t + \sum_{j=1}^{J} \beta_j \ controls_{tj} + \varepsilon_{it}$) tests Hypothesis 2a. The robust standard errors are reported. $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.10$.

product supply chain–as a producer or consumer. We followed Phan et al. (2019) in using two approaches to classify firms into crude oil consumers and producers. The first approach employs the Global Industry Classification Scheme, classifying a firm as a crude oil producer if it belongs to an industry that produces crude oil. In the second approach, we used the EIA website to collect data on crude oil production and national consumption for each of the 48 countries in our study. If a country's crude oil output is more (respectively, less) than its consumption, it is classified as a producer (respectively, consumer) of crude oil. We used two regression models:

$$DR_{it} = \alpha + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \beta_4 SDS \times Producer_{Industry_i} + \sum_{j=1}^{J} \beta_j \, controls_j + \varepsilon_{it} \tag{10}$$

$$DR_{it} = \alpha + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \beta_4 SDS \times Producer_{Country_i} + \sum_{j=1}^{J} \beta_j \, controls_j + \varepsilon_{it} \tag{11}$$

where $Producer_{Industry_i}$ is the dummy variable equal to 1 if the firm belongs to an industry that produces oil and 0 otherwise, and $Producer_{Country_i}$ is the dummy variable equal to 1 if the company is from an oil producer country and 0 otherwise.

Table 7 represents the coefficients, the robust standard errors for crude oil shocks, and the interaction of *SDS* with the energy industry dummy variable (Section A) and oil producer dummy variables (Section B). The findings indicate the following features. The results of the earlier analysis persist even after controlling for dummy variables in sections A and B, suggesting that oil *SS* decreases *DR*. In contrast, *SDS* and *ADS* positively affect *DR*. Second, belonging to the energy industry, they moderate the positive impact of a particular demand shock on distress risk, indicating that the firms' distress risk in energy-related industries is less affected by specific demand shocks. From Section A of Table 7, the coefficient of $SDS \times Energy\_ind$ is negative (−0.041) and significant ($p < 0.01$) for the Global panel. This evidence is consistent across developed countries, the Americas, Australasia, oil producers, and most firm characteristic panels. However, for the Africa panel, the coefficient of $SDS \times Energy\_ind$ is positive (0.149) and significant, indicating that firms in the energy industry are more susceptible to the positive impact of demand shocks on distress risk. The moderating effect of the energy industry is not notably observed in firms from the Emerging, Europe, Asia, and Consumer panels. Furthermore, companies with small BV, MV, and medium age do not experience the same benefits from being in the energy industry.

In addition, belonging to the oil producer country moderates the positive effect of oil *SDS* on distress risk. From Section B of Table 7, the coefficient of $SDS \times Producer$ is negative and significant ($p < 0.01$) for Global and Developed panels. This evidence suggests that oil-specific demand shocks affect the firms' distress risk in oil-producer countries less. Conversely, being a firm from an oil producer country in emerging and European regions does not have the same moderating impact. Furthermore, the results from the firm characteristics panels are consistent with those of the Global panel, showing the moderating effect of being in an oil producer country, regardless of firm *MV* and *BV*. Also, younger firms take more advantage of diversification than medium-to high-aged ones.

4.3.2. *Large vs. small and medium-sized Enterprises*

Empirical studies have shown that small firms face greater financial challenges and are less prepared to withstand shocks (e.g., Beck et al., 2005, 2008). To better understand how oil shocks affect the firms' *DR* based on size, we divided our sample into large and small to medium-sized firms (SMEs). Recognizing the limited representation of small companies within our dataset, we defined our size categories based on the number of employees, following Beck et al. (2005 and 2008). Specifically, we categorized firms with fewer than 500 employees as small to medium-sized, while those with 500 or more employees were counted as large-sized. We reanalyzed all models for these two subsamples and present the findings in Table 8.

First, the results of the earlier analysis persist across both subsamples, indicating that oil *SS* decreases the firms' *DR*. In contrast, oil *SDS* and *ADS* increase *DR*. Second, unlike large-sized firms, energy diversification does not significantly affect the *DR* of SMEs. Moreover, while energy diversification significantly ($p < 0.01$) moderates both the effects of *SS* and *SDS* on the firms' *DR* for large firms, it does not significantly moderate the effects of both demand shocks for SMEs and only moderates slightly ($p < 0.01$) the oil supply shock. Therefore, SMEs are less advantageous in terms of energy diversification.

4.3.3. *Managerial ability: low vs high*

Previous papers have extensively documented the impact of managerial ability on firm performance. High-ability managers, defined by a variety of criteria such as being hired away by other firms or demonstrating superior efficiency in resource transformation, have been shown to have a significant impact on various firm decisions and overall firm outcomes (Bertrand and Schoar, 2003; Demerjian et al., 2012). Managers with more remarkable abilities improve the firms' innovative input (Chen et al., 2015), earning quality (Demerjian et al., 2013), credit ratings (Cornaggia et al., 2017), and overall firm performance (Phan et al., 2020).

We used Demerjian et al.'s (2012) managerial ability measure to examine the impact of managerial ability on the relationship between oil shocks and firm distress risk. We followed Phan et al. (2020) to classify firms into low and high-efficiency groups based on their managerial average efficiency score. Then, we conducted analyses to investigate whether the impact of oil shocks on firm distress differs between these groups.

Model 1 in Table 9 for both subsamples is consistent with the results of prior analyses, indicating the negative impact of *SS* on the firms' *DR* and the positive effects of both oil *SDS* and *ADS* on the same. Additionally, the absolute values of the coefficients of the three oil shocks are higher for firms with a lower managerial ability, indicating a greater sensitivity of these firms' distress risk to oil shocks.

From Model 2, while energy diversification has a negative and significant impact ($p < 0.10$) on the distress risk of firms with a high managerial ability, it does not significantly affect those with low managerial ability. This indicates that firms with more capable

Table 7
Crude Oil Producers vs. Consumers.

	Section A: Producer Industry					Section B: Producer Country					
	SS	ADS	SDS	*SDS* × *Energy Ind.*	R-squared	SS	ADS	SDS	*SDS* × *Producer*	R-squared	Observations
Global	−0.072***	0.028***	0.121***	−0.041***	0.120	−0.072***	0.028***	0.137***	−0.015***	0.120	79,195
	(0.005)	(0.007)	(0.009)	(0.013)		(0.005)	(0.005)	(0.011)	(0.004)		
Developed	−0.086***	0.037***	0.157***	−0.058***	0.131	−0.085***	0.037***	0.157***	−0.002	0.130	48,743
	(0.007)	(0.006)	(0.012)	(0.017)		(0.007)	(0.006)	(0.015)	(0.005)		
Emerging	−0.058***	0.014*	0.074***	−0.012	0.123	−0.056***	0.013*	0.039*	0.030*	0.123	30,452
	(0.008)	(0.007)	(0.013)	(0.018)		(0.008)	(0.007)	(0.024)	(0.018)		
Americas	−0.096***	0.051***	0.208***	−0.070***	0.133	−0.091***	0.051***	0.261***	−0.078***	0.132	36,962
	(0.008)	(0.007)	(0.014)	(0.018)		(0.008)	(0.007)	(0.022)	(0.008)		
Europe	−0.037***	0.006	0.061***	0.023	0.139	−0.031***	0.005	−0.016	0.066**	0.140	22,495
	(0.011)	(0.008)	(0.020)	(0.029)		(0.012)	(0.008)	(0.038)	(0.026)		
Australasia	−0.115***	0.029*	0.116***	−0.080*	0.156	−0.115***	0.029*	0.112***	–	0.155	5525
	(0.022)	(0.017)	(0.032)	(0.043)		(0.022)	(0.017)	(0.032)			
Africa	−0.179	0.045	0.054	0.149***	0.205	−0.179	0.046	0.056	–	0.204	1417
	(0.169)	(0.057)	(0.252)	(0.028)		(0.168)	(0.057)	(0.250)			
Asia	−0.056***	−0.015	0.059***	−0.006	0.160	−0.056***	−0.015	0.067**	−0.008	0.160	12,796
	(0.010)	(0.012)	(0.020)	(0.025)		(0.010)	(0.012)	(0.031)	(0.022)		
Oil Producer	−0.109***	0.052***	0.207***	−0.086***	0.136	–	–	–	–		36,230
	(0.009)	(0.008)	(0.015)	(0.021)		–	–	–	–		
Oil Consumer	−0.049***	0.006	0.054***	−0.003	0.119						42,965
	(0.007)	(0.006)	(0.012)	(0.020)							
Panel B: Firm-characterized Panel											
High BV	−0.074***	0.012**	0.112***	−0.048***	0.105	−0.074***	0.012**	0.123***	−0.013*	0.103	27,947
	(0.007)	(0.006)	(0.012)	(0.016)		(0.007)	(0.006)	(0.015)	(0.006)		
Med BV	−0.097***	0.049***	0.158***	−0.057**	0.143	−0.097***	0.049***	0.179***	−0.014*	0.143	26,150
	(0.009)	(0.008)	(0.015)	(0.025)		(0.009)	(0.008)	(0.018)	(0.006)		
Low BV	−0.053***	0.029***	0.104***	−0.017	0.147	−0.053***	0.029***	0.123***	−0.020*	0.145	25,098
	(0.011)	(0.011)	(0.018)	(0.029)		(0.011)	(0.011)	(0.021)	(0.008)		
High MV	−0.036***	0.001	0.044***	−0.033***	0.055	−0.035***	0.001	0.029***	0.008**	0.054	27,731
	(0.004)	(0.004)	(0.007)	(0.012)		(0.004)	(0.004)	(0.009)	(0.004)		
Med MV	−0.087***	0.021***	0.128***	−0.043**	0.140	−0.087***	0.021***	0.154***	−0.029***	0.140	26,274
	(0.008)	(0.007)	(0.013)	(0.019)		(0.008)	(0.007)	(0.015)	(0.005)		
Low MV	−0.135***	0.090***	0.199***	−0.019	0.209	−0.135***	0.090***	0.225***	−0.027**	0.207	25,190
	(0.013)	(0.013)	(0.022)	(0.028)		(0.013)	(0.013)	(0.025)	(0.008)		
High Age	−0.052***	0.022***	0.071***	−0.042**	0.111	−0.052***	0.023***	0.076***	−0.005	0.110	28,311
	(0.007)	(0.007)	(0.013)	(0.021)		(0.007)	(0.008)	(0.007)	(0.005)		
Med Age	−0.068***	0.029***	0.096***	−0.032	0.129	−0.068***	0.029***	0.100***	−0.004	0.129	25,679
	(0.008)	(0.007)	(0.014)	(0.023)		(0.008)	(0.007)	(0.018)	(0.008)		
Low Age	−0.105***	0.039***	0.214***	−0.042*	0.133	−0.105***	0.038***	0.275***	−0.040***	0.134	25,205
	(0.011)	(0.01)	(0.02)	(0.021)		(0.011)	(0.01)	(0.025)	(0.09)		

Notes: The table presents the impact of the crude oil-producing industry and country on the relationship between crude oil price shocks and firm distance to default. The regression models are as follows: $DR_{it} = \alpha + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \beta_4 SDS_t \times Producer\_Industry_i + \sum_{j=1}^{J} \beta_j\ controls_{t-1j} + \varepsilon_{it}$ & $DR_{it} = \alpha + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \beta_4 SDS_t \times Producer\_Country_i + \sum_{j=1}^{J} \beta_j\ controls_{t-1j} + \varepsilon_{it}$. The robust standard errors are reported. The regressions control for year, industry fixed effects, while other control variables are not reported here. *T*-statistics are corrected by clustering the residuals at the firm level. ***p$<$ *0.01*, **p$<$ *0.05*, and * p$<$ *0.10*.

Table 8
Test of Hypotheses on Two Subsamples based on Firm Size.

	Panel A: Small and Medium Firms				Panel B: Large Firms			
Variable	Baseline	Model 1	Model 2	Model 3	Baseline	Model 1	Model 2	Model 3
SS		−0.052***	−0.053***	−0.095***		−0.077***	−0.076***	−0.119***
		(0.013)	(0.013)	(0.027)		(0.006)	(0.006)	(0.011)
SDS		0.088***	0.086***	0.097***		0.122***	0.121***	0.148***
		(0.023)	(0.023)	(0.032)		(0.010)	(0.010)	(0.014)
ADS		0.034***	0.035***	0.012		0.027***	0.026***	0.034***
		(0.013)	(0.013)	(0.026)		(0.005)	(0.005)	(0.009)
$log(ED_{t-1})$			0.006	0.007*			−0.004**	−0.004**
			(0.004)	(0.004)			(0.002)	(0.002)
$SS \times log(ED_{t-1})$				0.021*				0.023***
				(0.012)				(0.005)
$SDS \times log(ED_{t-1})$				−0.006				−0.015***
				(0.012)				(0.005)
$ADS \times log(ED_{t-1})$				0.013				−0.004
				(0.012)				(0.004)
$NITA_{t-1}$	0.008	0.008	0.008	0.008	−0.025	−0.025	−0.028*	−0.027*
	(0.007)	(0.007)	(0.007)	(0.007)	(0.015)	(0.015)	(0.016)	(0.016)
$TLTA_{t-1}$	0.078***	0.078***	0.078***	0.078***	0.078***	0.078***	0.078***	0.078***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.013)	(0.013)	(0.013)	(0.013)
$EXRET_{t-1}$	−0.037***	−0.037***	−0.037***	−0.037***	−0.046***	−0.046***	−0.046***	−0.046***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
$sig\ E_{t-1}$	0.061***	0.061***	0.060***	0.060***	0.105***	0.105***	0.104***	0.105***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)
BM_{t-1}	0.025***	0.025***	0.025***	0.025***	0.004	0.004	0.004	0.004
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
$CashTA_{t-1}$	−0.009	−0.009	−0.010	−0.010	−0.017	−0.017	−0.015	−0.015
	(0.009)	(0.009)	(0.009)	(0.009)	(0.024)	(0.024)	(0.024)	(0.024)
$Size_{t-1}$	0.008***	0.008***	0.008***	0.008***	0.001*	0.001*	0.001*	0.001*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
GDP_{t-1}	−0.080***	−0.080***	−0.075***	−0.072**	−0.036***	−0.036***	−0.043***	−0.042***
	(0.028)	(0.028)	(0.029)	(0.029)	(0.010)	(0.010)	(0.011)	(0.011)
Constant Term	−0.082***	−0.072***	−0.085***	−0.086***	−0.076***	−0.052***	−0.043***	−0.045***
	(0.012)	(0.012)	(0.016)	(0.016)	(0.007)	(0.006)	(0.007)	(0.007)
Observations	12,248	12,248	12,248	12,248	62,714	62,714	62,714	62,714
R-squared	0.138	0.138	0.138	0.138	0.116	0.116	0.117	0.117
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table displays the regression results indicating the impact of crude oil price shocks on the distress risk of two groups: small and medium firms, and large firms. *SS*, *ADS*, and *SDS* represent oil supply shocks, aggregate demand shocks, and oil-specific demand shocks, respectively. The baseline model includes control variables. Model 1 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \sum \beta_5 controls + \varepsilon_{it}$) tests Hypothesis 1a. Model 2 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 SDS_t + \beta_3 ADS_t + \beta_4 \times \log(ED_{t-1}) + \sum_{j=1}^{J} \beta_j\ controls_{tj} + \varepsilon_{it}$) examines the direct impact of energy diversity on distress risk. Model 3 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \beta_4\ log(ED_{t-1}) + \beta_5\ log(ED_{t-1}) \times SS_t + \beta_6\ log(ED_{t-1}) \times SDS_t + \beta_7\ log(ED_{t-1}) \times ADS_t + \sum_{j=1}^{J} \beta_j\ controls_{tj} + \varepsilon_{it}$) tests Hypothesis 2a, examining the moderating impact of energy diversity on *SDS*, as well as its moderating impact on two other sources of oil shocks, *ADS* and *SS*. The coefficients and robust standard errors are reported. ***$p < 0.01$, **$p < 0.05$, and * $p < 0.10$.

managers gain more from energy diversification strategies. In contrast, firms with less capable managers benefit less from such diversification.

From Model 3, for firms with low managerial ability, the coefficients of $SS \times log\ (ED)$ and $SDS \times log\ (ED)$ are both significant, with values of 0.025 and −0.016, respectively. The coefficient of $ADS \times log\ (ED)$ is negative but not significant. Therefore, the negative impact of *SS* on *DR* and the positive impact of *SDS* on *DR* are strengthened and mitigated, respectively, by higher energy diversification. For firms with high managerial ability, energy diversification interacts positively and significantly only with the impact of oil supply shock on the firms' *DR*.

Overall, these results highlight the crucial role of managerial ability in determining how effectively firms can use energy diversification to manage the risks associated with oil price shocks.

4.3.4. Financial constraints and distress risk: response to crude oil price shocks

This section examines whether oil shocks and energy diversification affect the firms' distress risk differently depending on their financial restrictions. Financial limitations can directly affect a firm's distress risk by reducing its capacity to absorb shocks and diversify its energy supply. We calculated the KZ index of Kaplan and Zingales (1997) following Lamont et al.'s (2001) methodology and divided the samples into two groups using the average KZ index for all firm-year observations. We then reanalyzed every model for

Table 9
Test of Hypotheses on Two Subsamples based on Managerial Ability.

	Panel A: Low Managerial Ability				Panel B: High Managerial Ability			
Variable	Baseline	Model 1	Model 2	Model 3	Baseline	Model 1	Model 2	Model 3
SS		−0.076***	−0.076***	−0.124***		−0.055***	−0.053***	−0.109***
		(0.008)	(0.009)	(0.016)		(0.009)	(0.009)	(0.019)
SDS		0.138***	0.138***	0.169***		0.093***	0.092***	0.108***
		(0.015)	(0.015)	(0.022)		(0.015)	(0.015)	(0.024)
ADS		0.033***	0.032***	0.045***		0.020**	0.019**	0.003
		(0.008)	(0.008)	(0.015)		(0.008)	(0.008)	(0.017)
$log(ED_{t-1})$			−0.001	−0.001			−0.005*	−0.005*
			(0.002)	(0.002)			(0.003)	(0.003)
$SS\times\ log(ED_{t-1})$				0.025***				0.029***
				(0.007)				(0.009)
$SDS\times\ log(ED_{t-1})$				−0.016**				−0.009
				(0.008)				(0.010)
$ADS\times\ log(ED_{t-1})$				−0.006				0.009
				(0.006)				(0.008)
$NITA_{t-1}$	0.006	0.006	0.006	0.007	0.014	0.014	0.012	0.012
	(0.012)	(0.012)	(0.012)	(0.012)	(0.014)	(0.014)	(0.014)	(0.014)
$TLTA_{t-1}$	0.077***	0.077***	0.077***	0.077***	0.073***	0.073***	0.073***	0.073***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.011)	(0.011)	(0.011)	(0.011)
$EXRET_{t-1}$	−0.047***	−0.047***	−0.047***	−0.047***	−0.042***	−0.042***	−0.042***	−0.042***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
$sig\ E_{t-1}$	0.100***	0.100***	0.100***	0.100***	0.073***	0.073***	0.072***	0.073***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)	(0.008)	(0.007)
BM_{t-1}	0.003	0.003	0.003	0.003	0.009**	0.009**	0.009**	0.009**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.004)	(0.004)
$CashTA_{t-1}$	0.010	0.010	0.010	0.010	−0.024*	−0.024*	−0.022	−0.023
	(0.018)	(0.018)	(0.018)	(0.018)	(0.014)	(0.014)	(0.014)	(0.014)
$Size_{t-1}$	0.003***	0.003***	0.003**	0.003**	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
GDP_{t-1}	−0.041**	−0.041**	−0.044**	−0.043**	−0.060***	−0.060***	−0.070***	−0.069***
	(0.016)	(0.016)	(0.017)	(0.017)	(0.019)	(0.019)	(0.020)	(0.020)
Constant Term	−0.078***	−0.054***	−0.051***	−0.053***	−0.057***	−0.039***	−0.027***	−0.029***
	(0.008)	(0.007)	(0.009)	(0.009)	(0.009)	(0.008)	(0.010)	(0.010)
Observations	29,478	29,478	29,478	29,478	19,310	19,310	19,310	19,310
R-squared	0.116	0.116	0.116	0.116	0.115	0.115	0.115	0.116
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table displays the regression results indicating the impact of crude oil price shocks on the distress risk of two distinct groups of firms: those with low managerial ability and those with high managerial ability. *SS*, *ADS*, and *SDS* represent oil supply shocks, aggregate demand shocks, and oil-specific demand shocks, respectively. The baseline model includes control variables. Model 1 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \sum \beta_5 controls + \varepsilon_{it}$) tests Hypothesis 1a. Model 2 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 SDS_t + \beta_3 ADS_t + \beta_4 \times \log(ED_{t-1}) + \sum_{j=1}^{J} \beta_j\ controls_{tj} + \varepsilon_{it}$) examines the direct impact of energy diversity on distress risk. Model 3 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \beta_4\ log(ED_{t-1}) + \beta_5\ log(ED_{t-1}) \times SS_t + \beta_6\ log(ED_{t-1}) \times SDS_t + \beta_7\ log(ED_{t-1}) \times ADS_t + \sum_{j=1}^{J} \beta_j\ controls_{tj} + \varepsilon_{it}$) tests Hypothesis 2a, examining the moderating impact of energy diversity on *SDS,* as well as its moderating impact on two other sources of oil shocks, *ADS* and *SS*. Robust standard errors are reported. ***$p < 0.01$, **$p < 0.05$, and * $p < 0.10$.

these two subsamples, and Table 10 shows the related results.

Panel A of Table 10 presents the regression results for non-constrained firms. While the coefficients of *SS* and *SDS* are consistent with prior findings (i.e., they are negative and positive, respectively), the coefficient of *ADS* is negative and significant ($p < 0.10$). These findings suggest that for non-constraint firms, both *SS* and *ADS* reduce distress risk, while *SDS* increases distress risk. Also, for non-constraint firms, energy diversification does not directly affect a firm's *DR*. However, the adverse effects of *SS* and *ADS* on *DR* are strengthened by higher energy diversification.

Panel B of Table 10 also demonstrates the regression results for financially constrained firms. The direction and significance level of coefficients for all oil shocks in Models 1, 2, and 3 are consistent with the results of prior analyses, indicating the negative impact of *SS* on firms' *DR* and the positive effects of both oil *SDS* and *ADS* on firms' *DR.* Energy diversification reduces the distress risk significantly ($p < 0.05$). The negative impact of *SS* on *DR* and the positive impact of *SDS* on *DR* are strengthened and mitigated, respectively, by higher energy diversification.

These findings reinforce the crucial role that financial constraints play in determining a firm's responses to oil shocks and the significance of energy diversification as a risk management approach, especially for financially constrained companies.

Table 10
Test of Hypotheses on Two Subsamples based on the KZ Index.

	Panel A: Financial Non-Constrained Firms				Panel B: Financial Constrained Firms			
Variable	Baseline	Model 1	Model 2	Model 3	Baseline	Model 1	Model 2	Model 3
SS		−0.018***	−0.017***	−0.045***		−0.110***	−0.108***	−0.168***
		(0.004)	(0.004)	(0.009)		(0.008)	(0.008)	(0.017)
SDS		0.020***	0.020***	0.021**		0.185***	0.185***	0.226***
		(0.006)	(0.006)	(0.009)		(0.014)	(0.014)	(0.022)
ADS		−0.007*	−0.007**	−0.015**		0.051***	0.050***	0.062***
		(0.004)	(0.004)	(0.006)		(0.007)	(0.007)	(0.014)
$log(ED_{t-1})$			−0.001	−0.000			−0.006**	−0.005**
			(0.001)	(0.001)			(0.003)	(0.003)
$SS \times log(ED_{t-1})$				0.015***				0.031***
				(0.004)				(0.007)
$SDS \times log(ED_{t-1})$				−0.001				−0.022**
				(0.003)				(0.008)
$ADS \times log(ED_{t-1})$				0.005*				−0.005
				(0.003)				(0.006)
$NITA_{t-1}$	0.009***	0.009***	0.009***	0.009***	0.011	0.011	0.011	0.011
	(0.003)	(0.003)	(0.003)	(0.003)	(0.011)	(0.011)	(0.011)	(0.011)
$TLTA_{t-1}$	0.031***	0.031***	0.031***	0.031***	0.094***	0.094***	0.094***	0.094***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.015)	(0.015)	(0.015)	(0.015)
$EXRET_{t-1}$	−0.011***	−0.011***	−0.011***	−0.011***	−0.060***	−0.060***	−0.060***	−0.060***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)
$sig\ E_{t-1}$	0.029***	0.029***	0.029***	0.029***	0.113***	0.113***	0.113***	0.113***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.008)	(0.008)	(0.008)	(0.008)
BM_{t-1}	0.007***	0.007***	0.007***	0.007***	0.004	0.004	0.004	0.004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
$CashTA_{t-1}$	−0.018***	−0.018***	−0.018***	−0.018***	−0.001	−0.001	−0.000	−0.000
	(0.005)	(0.005)	(0.005)	(0.005)	(0.019)	(0.019)	(0.019)	(0.019)
$Size_{t-1}$	0.000	0.000	0.000	0.000	0.003***	0.003***	0.002***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
GDP_{t-1}	0.009	0.009	0.008	0.010	−0.057***	−0.057***	−0.065***	−0.063***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.015)	(0.015)	(0.016)	(0.016)
Constant Term	−0.031***	−0.022***	−0.020***	−0.021***	−0.091***	−0.061***	−0.049***	−0.050***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.009)	(0.008)	(0.010)	(0.010)
Observations	32,403	32,403	32,403	32,403	42,559	42,559	42,559	42,559
R-squared	0.055	0.055	0.055	0.056	0.131	0.131	0.131	0.131
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table displays the regression results indicating the impact of crude oil price shocks on the distress risk of two groups of firms: financially constrained and financially non-constrained. *SS*, *ADS*, and *SDS* represent oil supply shocks, aggregate demand shocks, and oil-specific demand shocks. The baseline model includes control variables. Model 1 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \sum \beta_5 controls + \varepsilon_{it}$) tests Hypothesis 1a. Model 2 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 SDS_t + \beta_3 ADS_t + \beta_4 \times \log(ED_{t-1}) + \sum_{j=1}^{J} \beta_j\ controls_{tj} + \varepsilon_{it}$) examines the direct impact of energy diversity on distress risk. Model 3 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \beta_4\ log(ED_{t-1}) + \beta_5\ log(ED_{t-1}) \times SS_t + \beta_6\ log(ED_{t-1}) \times SDS_t + \beta_7\ log(ED_{t-1}) \times ADS_t + \sum_{j=1}^{J} \beta_j\ controls_{tj} + \varepsilon_{it}$) tests Hypothesis 2a, examining the moderating impact of energy diversity on *SDS*, as well as its moderating impact on two other sources of oil shocks, *ADS* and *SS*. Robust standard errors are reported. ***$p < 0.01$, **$p < 0.05$, and * $p < 0.10$.

4.3.5. Financial crises vs. normal years

We expect that crude oil price shocks exert different impacts on firm distress during crises. We used the following regression model to assess this impact, and the results are reported in Table 11.

$$DR_{it} = \alpha + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \beta_4 SDS_t \times CRISES_t + \sum_{j=1}^{J} \beta_j\ controls_j + \varepsilon_{it} \tag{12}$$

CRISES is a dummy variable equal to 1 for firm-year observations during the Global Financial Crisis (2007 and 2008) and the COVID-19 period (2020 and 2021), and 0 otherwise. Table 11 shows the coefficients for the three different crude oil shocks (*SS*, *ADS*, and *SDS*), as well as the interaction between *SDS* and the dummy variable for the related two crises.

The results remain consistent with the previous analyses regarding the effect of crises. Notably, the coefficient of *SDS*× *CRISES* shows a positive and significant impact, ranging from 0.128 to 0.358, in most panels, including Global, Developed, Emerging, Americas, Europe, Australasia, and oil producers, as well as the firm characteristic panels. These results indicate a substantial increase in the effect of specific demand shocks on firm distress, particularly during times of crisis. Notably, the coefficient of *SDS*× *CRISES* for oil producers is positive (0.358) and significant ($p < 0.01$) in contrast to consumers, which is insignificant. Therefore, firms in

Table 11
The impact of global financial crisis.

	SS	*SDS*	*ADS*	*SDS × CRISIS*	Observations	R-squared
Panel A: Aggregate Market Panels						
Global	−0.114***	0.229***	−0.001	0.184***	79,195	0.119
	(0.011)	(0.028)	(0.007)	(0.040)		
Developed	−0.136***	0.288***	0.001	0.224***	48,743	0.13
	(0.015)	(0.036)	(0.009)	(0.052)		
Emerging	−0.086***	0.148***	−0.006	0.128**	30,452	0.122
	(0.018)	(0.042)	(0.011)	(0.060)		
Americas	−0.168***	0.393***	0.002	0.315***	36,962	0.131
	(0.019)	(0.046)	(0.011)	(0.067)		
Europe	−0.067***	0.142***	−0.017	0.134*	22,495	0.138
	(0.022)	(0.052)	(0.012)	(0.070)		
Australasia	−0.184***	0.295***	−0.022	0.293**	5525	0.172
	(0.048)	(0.109)	(0.020)	(0.145)		
Africa	−0.247	0.194	−0.004	0.154	1417	0.216
	(0.310)	(0.619)	(0.135)	(0.620)		
Asia	−0.075***	0.111*	−0.029*	0.081	12,796	0.163
	(0.024)	(0.058)	(0.016)	(0.075)		
Oil Producer	−0.188***	0.423***	0.001	0.358***	36,230	0.134
	(0.019)	(0.046)	(0.011)	(0.066)		
Oil Consumer	−0.063***	0.093***	−0.003	0.062	42,965	0.117
	(0.014)	(0.035)	(0.009)	(0.048)		
Panel B: Firm-characterized Panel						
High BV	−0.088***	0.150***	−0.002	0.07	27,947	0.101
	(0.014)	(0.034)	(0.008)	(0.047)		
Med BV	−0.168***	0.343***	0.001	0.311***	26,150	0.14
	(0.019)	(0.047)	(0.012)	(0.068)		
Low BV	−0.128***	0.293***	−0.023	0.287***	25,098	0.159
	(0.028)	(0.066)	(0.015)	(0.096)		
High MV	−0.026***	0.016	0.007	−0.042	27,731	0.053
	(0.008)	(0.019)	(0.005)	(0.027)		
Med MV	−0.082***	0.108***	0.026***	−0.024	26,274	0.136
	(0.016)	(0.037)	(0.009)	(0.053)		
Low MV	−0.213***	0.393***	0.039**	0.322***	25,190	0.208
	(0.031)	(0.073)	(0.018)	(0.107)		
High Age	−0.072***	0.124***	0.008	0.089*	28,311	0.11
	(0.016)	(0.039)	(0.009)	(0.053)		
Med Age	−0.119***	0.233***	−0.008	0.225***	25,679	0.129
	(0.019)	(0.047)	(0.012)	(0.068)		
Low Age	−0.159***	0.358***	0.001	0.238***	25,205	0.133
	(0.026)	(0.062)	(0.015)	(0.092)		

Notes: The table presents the impact of global financial crises on the relationship between crude oil price shocks and firm distress risk. The regression model is as follows: $DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 SDS_t + \beta_3 ADS_t + \beta_4 SDS_t \times CRISIS_t + \sum_{j=1}^{J} \beta_j\ controls_{t-1j} + \varepsilon_{it}$. The regression controls for year and industry fixed effects, while other control variables are not reported here. T-statistics are corrected by clustering the residuals at the firm level. Robust standard errors are reported. ***p< 0.01, **p< 0.05, and * p< 0.10.

countries reliant on oil exports have been disproportionately affected by global crises. These results highlight the importance of understanding the dynamics of financial distress and the increased potency of oil demand shocks on firm distress during crisis periods, especially when the economy is facing major obstacles.

Upon further examination, we split the sample into two groups: one for the crisis periods of 2007, 2008, 2020, and 2021, and another for the non-crisis periods containing the other years. We then reanalyzed all models for these two subsamples and the results are in Table 12. The results indicate that during the crisis years, *SDS* had a positive and significant impact on *DR* ($p < 0.01$). Conversely, *SS* and *ADS* have adverse and significant effects on *DR* ($p < 0.01$). In addition, energy diversification neither directly affects *DR* nor moderates the relationship between oil shocks and *DR*.

Notably, all oil shocks positively and significantly affect DR during the years without crises. Additionally, energy diversification reduces a firm's *DR* and has a significant and positive moderating effect on the relationship between supply shocks and *DR*.

4.3.6. Other Alternatives Measures and robustness checks

We also considered the additional robustness checks to emphasize the robustness of the findings.

Alternative Measures for the Probability of Default: In the first robustness check, we followed standard research practices by using two commonly used measures for distress risk: Altman's (1968) z-score and Zmijewski's (1984) score. The findings are displayed in Appendix Tab I. Using both distress measures, *SDS* shows a positive and statistically significant impact on firms' distress risk ($p < 0.01$), which is consistent with the main findings. Conversely, supply shock (*SS*) demonstrates a significant and negative effect on firm

Table 12
Test of hypotheses on two subsamples based on financial crisis years.

	Panel 1: Financial Crisis Period				Panel 2: Non-Financial Crisis Period			
Variable	Baseline	Model 1	Model 2	Model 3	Baseline	Model 1	Model 2	Model 3
SS		−0.101***	−0.100***	−0.167***		1.758***	1.746***	1.730***
		(0.009)	(0.009)	(0.019)		(0.143)	(0.143)	(0.144)
SDS		0.247***	0.247***	0.289***		2.070***	2.056***	2.078***
		(0.027)	(0.028)	(0.051)		(0.163)	(0.163)	(0.163)
ADS		−0.070***	−0.069***	−0.036*		0.013*	0.013*	0.017
		(0.008)	(0.009)	(0.021)		(0.007)	(0.007)	(0.011)
$log(ED_{t-1})$			0.000	0.001			−0.004**	−0.003*
			(0.003)	(0.003)			(0.002)	(0.002)
$SS \times log(ED_{t-1})$				−0.034				−0.018**
				(0.024)				(0.007)
$SDS \times log(ED_{t-1})$				−0.015				−0.022**
				(0.011)				(0.005)
$ADS \times log(ED_{t-1})$				0.039***				−0.004
				(0.010)				(0.010)
$NITA_{t-1}$	0.020	0.020	0.020	0.021	−0.001	−0.001	−0.002	−0.002
	(0.015)	(0.015)	(0.015)	(0.015)	(0.008)	(0.008)	(0.008)	(0.008)
$TLTA_{t-1}$	0.082***	0.082***	0.082***	0.082***	0.078***	0.078***	0.079***	0.079***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.008)	(0.008)	(0.008)	(0.008)
$EXRET_{t-1}$	−0.036***	−0.036***	−0.036***	−0.036***	−0.052***	−0.052***	−0.052***	−0.052***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
$sigE_{t-1}$	0.070***	0.070***	0.070***	0.070***	0.112***	0.112***	0.112***	0.112***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.006)	(0.006)	(0.006)	(0.006)
BM_{t-1}	0.022***	0.022***	0.022***	0.022***	0.004	0.004	0.004	0.004
	(0.004)	(0.004)	(0.004)	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)
$CashTA_{t-1}$	−0.036**	−0.036**	−0.036**	−0.037**	0.020	0.020	0.020*	0.021*
	(0.017)	(0.017)	(0.017)	(0.018)	(0.012)	(0.012)	(0.012)	(0.012)
$Size_{t-1}$	0.004***	0.004***	0.004***	0.004***	0.001**	0.001**	0.001**	0.001**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
GDP_{t-1}	−0.091***	−0.091***	−0.090***	−0.080***	−0.020*	−0.020*	−0.027**	−0.029**
	(0.017)	(0.017)	(0.018)	(0.019)	(0.011)	(0.011)	(0.011)	(0.011)
Constant Term	−0.064***	−0.072***	−0.072***	−0.077***	−0.079***	0.141***	0.147***	0.145***
	(0.008)	(0.008)	(0.010)	(0.010)	(0.006)	(0.016)	(0.017)	(0.017)
Observations	21,531	21,531	21,531	21,531	57,664	57,664	57,664	57,664
R-squared	0.134	0.134	0.134	0.135	0.117	0.117	0.118	0.118
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table displays the regression results indicating the impact of crude oil price shocks on the distress risk of two distinct periods: crises vs. normal. *SS*, *ADS*, and *SDS* represent oil supply shocks, aggregate demand shocks, and oil-specific demand shocks. The baseline model includes control variables. Model 1 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \sum \beta_5 controls + \varepsilon_{it}$) tests Hypothesis 1a. Model 2 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 SDS_t + \beta_3 ADS_t + \beta_4 \times \log(ED_{t-1}) + \sum_{j=1}^{J} \beta_j\ controls_{tj} + \varepsilon_{it}$) examines the direct impact of energy diversification on distress risk. Model 3 ($DR_{it} = \alpha_i + \beta_1 SS_t + \beta_2 ADS_t + \beta_3 SDS_t + \beta_4\ log(ED_{t-1}) + \beta_5\ log(ED_{t-1}) \times SS_t + \beta_6\ log(ED_{t-1}) \times SDS_t + \beta_7\ log(ED_{t-1}) \times ADS_t + \sum_{j=1}^{J} \beta_j\ controls_{tj} + \varepsilon_{it}$) tests Hypothesis 2a, examining the moderating impact of energy diversification on *SDS* and its moderating impact on two other sources of oil shocks, *ADS* and *SS*. Robust standard errors are reported. ***$p < 0.01$, **$p < 0.05$, and * $p < 0.10$.

distress ($p < 0.01$). Considering the Zmijewski score, the results suggest a negative and statistically significant ($p < 0.01$) coefficient for $SDS \times log\ (ED)$, underscoring the pivotal moderating role of energy diversification in shaping the relationship between *SDS* and firm distress risk.

Alternative Measures of Crude Oil Uncertainty: In the second robustness check, we used two alternative metrics to measure crude oil price uncertainty: the variance obtained from the GARCH (1,1) model and the standard deviation of oil price changes (σ). The existing literature has extensively employed these measures (Henriques and Sadorsky, 2011; Wang et al., 2017). The related regression results are in Appendix Tab II, supporting the main findings. As determined through both metrics, the estimated crude oil volatility exerts a positive and statistically significant ($p < 0.01$) effect on firm distress. Furthermore, the moderating effect of energy diversification on this relationship was also observed. Specifically, energy diversification weakens the positive impact of oil shocks on firm distress, highlighting the crucial role of diversified energy sources in mitigating the adverse consequences of oil price fluctuations on firm financial stability.

5. Conclusion

This paper examined the impact of various sources of oil price shocks on global firms' distress. Specifically, we decomposed oil prices into oil supply shocks, aggregate demand shocks, and oil-specific demand shocks using the SVAR framework introduced by

Kilian (2009). Using observations for 8130 firms from 48 countries between 2002 and 2022, we evaluated the impact of these three oil shocks on firm distress risk. We grouped the firms into panels: a global panel comprising all firms, a panel for developed countries, a panel for emerging countries, panels based on five continents, and nine panels created based on firm characteristics, such as market value, book value, and age. Furthermore, we investigated the moderating impact of energy diversification on the relationship between oil shocks and firm distress.

The main findings considering the two hypotheses can be outlined as follows. Considering Hypothesis 1a, the primary results reveal that both oil demand shocks - aggregate and specific - positively and significantly affect a firm's distress risk. In contrast, oil supply shocks negatively and substantially affects a firm's distress risk. These findings are robust across most panels except in Africa, where no significant impact of oil shocks on firms' distress is observed. For firms in the crude oil industry or oil-producing countries, there is a reduction in the effect of specific demand shocks on firm distress. The impact is more substantial during global financial crises. For the global, American, and oil producer panels, energy diversification negatively moderates the effects of a specific demand shock on firm distress risk. This evidence implies that firms in countries with more diversified energy sources are less susceptible to distress risk resulting from oil demand shocks, supporting the validity of Hypothesis 2a.

In contrast, in the emerging, Asia, Africa, and consumer panels, energy diversification raises the detrimental impact of oil demand shocks on firms' distress. These findings remain robust across various alternative tests. Therefore, there are significant differences between developed and developing countries where Hypotheses 1b and 2b are valid.

This research on the effect of oil price shocks on corporate distress risk has important policy implications, which we have explored in the findings. Policymakers and regulators should extend their understanding of oil price shocks beyond simple variations and investigate their underlying causes. It is important to emphasize that developing effective strategies requires a comprehensive knowledge of these shocks. As Kilian (2014) discussed, demand-side factors and supply-side disruptions are primary drivers of oil price shocks. Additionally, geopolitical factors, such as conflicts, instability, and sanctions, significantly influence these shocks. Resource Curse theory suggests that countries rich in natural resources, like oil, may experience economic and political instability. This instability can lead to fluctuations in oil production and export, affecting global prices. The resource curse is often attributed to corruption, a lack of economic diversification, and rent-seeking behavior (Savoia and Sen, 2021).

Considering the investigation into the moderating effect of energy diversification at the country level, regulators and policymakers should give special attention to initiatives that promote competition within the energy sector while simultaneously promoting diversification. In addition, understanding the moderating effect of energy diversification can provide insights into how countries can better manage the impact of energy price shocks on a firm's financial performance, with potential policy implications for energy diversification and risk management. These policies are noteworthy for reducing the negative impact of oil-specific demand shocks on a firm's distress risk.

Finally, it is essential to note that this study has limitations. For instance, the lack of control over firm-level hedging strategies can significantly affect a firm's distress risk during oil price shocks. While we accounted for firm-level managerial ability and industry-fixed effects, our dataset does not contain comprehensive information on using currency, commodities derivatives, or other risk management measures that firms might implement during the crises. Following the spirit of Adekoya and Oliyide (2020), Chun et al. (2019), Guay and Kothari (2003), and Purnanandam (2008), future papers can incorporate firm-level hedging data to improve awareness regarding how firms reduce the impact of oil shocks. Additionally, dividing the sample into hedging and non-hedging firms may provide important insight about the cross-sectional heterogeneity in distress risk responses. Future studies should also control the CEO risk-taking behavior and/or risk-taking incentives in the empirical models.

CRediT authorship contribution statement

Mohammad Mahdi Mousavi: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Giray Gozgor:** Writing – review & editing. **Albert Acheampong:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix

Table I
Alternative Measures of Default Probability

Panel A: Altman Z-Score					Panel B: Zmijewski Score			
Variable	Baseline	Model 1	Model 2	Model 3	Baseline	Model 1	Model 2	Model 3
SS		−0.013***	−0.013***	−0.036***		−0.035***	−0.038***	−0.052***
		(0.005)	(0.005)	(0.007)		(0.006)	(0.006)	(0.009)
SDS		0.052***	0.052***	0.058***		0.046***	0.048***	0.083***
		(0.010)	(0.010)	(0.012)		(0.012)	(0.012)	(0.015)
ADS		−0.006	−0.006	0.001		0.018**	0.020***	0.017
		(0.005)	(0.005)	(0.008)		(0.007)	(0.007)	(0.011)
$log(ED_{t-1})$			0.001	0.001			0.009***	0.009***
			(0.002)	(0.002)			(0.003)	(0.003)
$SS\times\ log(ED_{t-1})$				0.012***				0.008**
				(0.003)				(0.004)
$SDS\times\ log(ED_{t-1})$				−0.003				−0.019***
				(0.004)				(0.005)
$ADS\times\ log(ED_{t-1})$				−0.003				0.002
				(0.003)				(0.005)
$NITA_{t-1}$	−0.204***	−0.204***	−0.204***	−0.204***	−0.140***	−0.140***	−0.138***	−0.138***
	(0.033)	(0.033)	(0.033)	(0.033)	(0.045)	(0.045)	(0.044)	(0.044)
$TLTA_{t-1}$	0.136***	0.136***	0.136***	0.136***	0.544***	0.544***	0.544***	0.544***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.059)	(0.059)	(0.059)	(0.059)
$EXRET_{t-1}$	−0.063***	−0.063***	−0.063***	−0.063***	−0.054***	−0.054***	−0.054***	−0.053***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
$sigE_{t-1}$	0.121***	0.121***	0.121***	0.121***	0.152***	0.152***	0.153***	0.153***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.015)	(0.015)	(0.015)	(0.015)
BM_{t-1}	0.003	0.003	0.003	0.003	−0.001	−0.001	−0.001	−0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
$CashTA_{t-1}$	−0.114***	−0.114***	−0.115***	−0.115***	−0.115*	−0.115*	−0.116*	−0.116*
	(0.035)	(0.035)	(0.035)	(0.035)	(0.068)	(0.068)	(0.068)	(0.068)
$Size_{t-1}$	−0.004***	−0.004***	−0.004***	−0.004***	0.011***	0.011***	0.011***	0.011***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)
GDP_{t-1}	−0.098***	−0.098***	−0.097***	−0.095***	−0.090***	−0.090***	−0.074***	−0.076***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.015)	(0.015)	(0.014)	(0.014)
Constant Term	−0.026***	−0.011	−0.013	−0.014	−0.233***	−0.226***	−0.246***	−0.246***
	(0.008)	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)	(0.012)	(0.012)
Observations	74,825	74,825	74,825	74,825	76,200	76,200	76,200	76,200
R-squared	0.281	0.281	0.281	0.281	0.456	0.456	0.456	0.456
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table presents the robustness check of the impact of crude oil shocks on firm distress risk, estimated by the Altman z-score and the Zmijewski score with global panel data. *SS*, *ADS*, and *SDS* represent oil supply shocks, aggregate demand shocks, and oil-specific demand shocks, respectively. The baseline model includes control variables. *T*-statistics are corrected by clustering the residuals at the firm level. Robust standard errors are reported. $***p < 0.01$, $**p < 0.05$, *and* $*\ p < 0.10$.

Appendix

Table II
Alternative Measures of Oil Shocks

	Model 1	Model 2	Model 3	Model 4
$Garch_{oil}\ (1,1)$	2.743***	3.373***	–	–
	(1.016)	(1.024)		
$Garch_{oil}\ (1,1)\times\ \log\ (ED)$	–	−0.182***	–	–
		(0.052)		
σ_{oil}	–	–	2.601***	3.369***
			(0.964)	(1.032)
$\sigma_{oil}\times log\ (ED_{t-1})$	–	–	–	−0.316*
				(0.185)
$\log\ (ED_{t-1})$	–	0.009**	–	−0.001
		(0.004)		(0.002)

(*continued on next page*)

Table II (*continued*)

	Model 1	Model 2	Model 3	Model 4
$NITA_{t-1}$	0.001	0.001	0.001	0.001
	(0.008)	(0.008)	(0.008)	(0.008)
$TLTA_{t-1}$	0.079***	0.079***	0.079***	0.079***
	(0.009)	(0.009)	(0.009)	(0.009)
$EXRET_{t-1}$	−0.049***	−0.050***	−0.049***	−0.050***
	(0.002)	(0.002)	(0.002)	(0.002)
$sigE_{t-1}$	0.102***	0.101***	0.102***	0.101***
	(0.005)	(0.005)	(0.005)	(0.005)
BM_{t-1}	0.005**	0.005**	0.005**	0.005**
	(0.002)	(0.002)	(0.002)	(0.002)
$CashTA_{t-1}$	0.005	0.006	0.005	0.006
	(0.011)	(0.011)	(0.011)	(0.011)
$Size_{t-1}$	0.002***	0.002***	0.002***	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)
GDP_t	−0.054***	−0.057***	−0.054***	−0.058***
	(0.010)	(0.010)	(0.010)	(0.010)
Constant Term	−0.307***	−0.348***	−0.096***	−0.094***
	(0.086)	(0.086)	(0.009)	(0.010)
Observations	80,151	80,151	80,151	80,151
R-squared	0.120	0.120	0.120	0.120
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes

Notes: The table presents the robustness check of the impact of crude oil volatility, estimated using GARCH (1,1) and standard deviation (σ), on firm probability of default, using global panel data. Models 1 and 3 $\left(DR_{it} = \alpha_i + \beta_1 OILVOL_t + \sum_{j=1}^{J} \beta_j \, controls_{tj} + \varepsilon_{it}\right)$ test Hypothesis 1a. Models 2 and 4 ($DR_{it} = \alpha_i + \beta_1 OILVOL_t + \beta_2 \log(ED_t) \times OILVOL_t + \sum_{j=1}^{J} \beta_j \, controls_{t-1j} + \varepsilon_{it}$) test Hypothesis 2a. OILVOL is estimated by GARCH (1,1) in Models 1 and 2, and using σ in Models 3 and 4. *T*-statistics are corrected by clustering the residuals at the firm level. Robust standard errors are reported. ***$p < 0.01$, **$p < 0.05$, and * $p < 0.10$.

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