



Oil price uncertainty and the cost of debt: Evidence from the Chinese bond market

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ABSTRACT

This paper explores the impact of oil price uncertainty affects the cost of debt in China. By analyzing the bond data from 2008 to 2019 in China, we find that oil price fluctuation boost bond offering spread, denoting that oil price uncertainty may increase the cost of debt. This increase is likely due to higher default risks resulting from the heightened oil price uncertainty. Moreover, non-state-owned firms and those in the energy industry are more susceptible to the effects of oil price volatility. Our findings also reveal an asymmetric effect of oil price uncertainty on the cost of debt, with a stronger impact observed from positive uncertainty compared to negative uncertainty. This study contributes to the current understanding of the ways in which oil price uncertainty impacts the cost of debt in an emerging country.

1. Introduction

Crude oil is crucial for financial markets and economic development (Alsaman, 2016; Crawford et al., 2021). Much literature documents that crude oil serves as a critical input factor for production, and its price uncertainty directly or indirectly exert a detrimental effect on corporate operations, such as corporate investment (Henriques & Sadorsky, 2011), corporate leverage (Fan et al., 2021), corporate innovation (Amin et al., 2023), corporate payouts policy (Wong & Hasan, 2021), and performance (Phan et al., 2020).² However, the impact of oil price fluctuations on the cost of debt is unexplored, specifically on bond offering spread. To bridge

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² Although many firms do not use crude oil in their production process, they are still indirectly impacted by it. For instance, crude oil can affect transportation costs and thus indirectly affect firms' operations as many firms need transport products or workers. Additionally, these companies may also utilize petroleum products which typically include a significant amount of crude oil in its retail price.

this research gap, our study investigates whether oil price fluctuations impact the cost of debt.³

It is crucial and urgent to explore the link between oil price uncertainty (OPU) and the cost of debt in China. First, as the largest oil import country, China depends heavily on crude oil. Economic activity and financial markets are prone to be substantially influenced by oil price fluctuation (Fan et al., 2021). As the largest emerging market, China has a developing financial system, and its firms experience higher financing costs than mature markets, which also exist in other emerging countries (Amstad & He, 2019). Therefore, exploring its impact on the cost of debt can guide developing countries to reduce their firms' financing costs. Second, bondholders and shareholders have different risk preferences, as they are different types of claimants of firms (Chen et al., 2021). Specifically, bondholders are fixed claimants, whereas shareholders are residual claimants. This implies that the payoff structure is asymmetric for these two groups, making bondholders more sensitive to downside risks than other stakeholders (Boubakri & Ghouma, 2010), and thus they may require a higher premium to compensate for these downside risks (Lin et al., 2013). Accordingly, bondholders should have a clear comprehension of the detrimental implications of oil price fluctuation. Analyzing how oil price uncertainty influences bond offering spread can offer insights into how it affects bondholders' perceptions of risk.

Motivated by the studies on oil price uncertainty and debt financing cost (Jiang, 2008), this study proposes that oil price fluctuation can impact the cost of debt by raising bond issuers' default risks. Theoretically, as an essential input factor for firms' production process, its price uncertainty could denote a significant uncertainty for firms that may influence firms' decision process (Phan et al., 2019; Amin et al., 2023). Firstly, increased oil price fluctuations can lead firms to postpone investments until stability (Caballero, 1991; Bloom et al., 2007). However, the postponement in investment may lead to losses in profitable investment opportunities and adversely affect firms' fundamentals, which may weaken firms' repayability and thus increase issuers' default risks (Chiah et al., 2022). Secondly, increased oil price uncertainty can intensify the information asymmetry between firms and bondholders, thereby amplifying default risks. (Hasan et al., 2022). Thirdly, oil price uncertainty may have a similar impact on consumer behaviors. As documented by Edelstein and Kilian (2009) and Baumeister et al. (2018), oil price uncertainty could diminish consumers' purchasing power and disposable income, leading to decreased consumption expenditure. Therefore, oil price uncertainty may lead to fewer demands for firms' products or services, which may also hurt the firm's fundamentals, resulting in higher default risks (Phan et al., 2020; Chiah et al., 2022). As default risk is a crucial factor influencing the cost of debt (Jiang, 2008; Boubakri & Ghouma, 2010), oil price uncertainty will inevitably increase bond offering spreads (i.e., the cost of debt).

We begin our analysis by investigating whether oil price fluctuation affects the cost of debt. Estimated results show that bond offering spread statistically and significantly increases when crude oil price fluctuation inclines, indicating that oil price fluctuation increases the cost of debt. In addition, this detrimental effect has economic significance as well. The bond offering spread rises by at least 7.8% when a one-standard deviation rises in oil price fluctuation. Our basic regression result continues to hold after we conduct numerous robustness checks.

We then discuss the potential mechanism through which oil price uncertainty impacts the cost of debt. To this end, we use two proxies for firms' default risks, as constructed by Chen et al. (2022). Then, we expect a significant increase in firms' default risks as oil price uncertainty increases. Our empirical results align with the theoretical hypothesis that oil price fluctuations escalate firms' default risks, indicating that the elevated effect of oil price volatility on the debt financing cost can be attributed to an increase in firms' default risks.

Furthermore, we conduct two heterogeneity analyses. First, we explore the moderate effect of SOEs by adding the interaction of state-owned dummy (SOE) and oil price uncertainty. The heterogeneous results demonstrate that the adverse effect of oil price fluctuation on the debt financing cost is less prominent for bonds issued by SOEs, suggesting that SOE firms experience a less adverse impact relative to non-SOE firms. Second, following Bouri et al. (2017), we also explore the moderate effect of oil usage intensity by adding the interaction term of the oil usage intensity dummy (ERI) and oil price uncertainty. Our results show that bonds issued by firms from energy-related industries have a greater increased effect compared to bonds issued by firms with a low oil usage intensity. It indicates that oil usage intensity enhances the adverse effect of oil price fluctuation as these firms affect more by oil price.

Lastly, we test the asymmetric and nonlinear effects of oil price volatility on the cost of debt. To assess the asymmetric impact of oil price fluctuation, we decompose OPU into positive and negative oil price uncertainty based on related literature (Rahman & Serletis, 2011; Segal et al., 2015). The results reveal that positive oil price fluctuation has a more pronounced impact on the cost of debt relative to negative oil price uncertainty. This can be explained by the fact that positive (negative) oil price fluctuations are perceived as bad (good) news, suggesting that debtholders are more vulnerable to negative news (Xiao et al., 2018). Moreover, to examine the nonlinear effect, we add a squared term of oil price fluctuation. Our results suggest that such a nonlinear effect exists, specifically in the form of an inverted U-shaped link between oil price fluctuation and debt financing cost.

Our study makes the following contributions to the current literature. Firstly, we contribute to the research discussing the impact of oil price fluctuations on corporate activities. Previous research has concentrated on the impact of oil price fluctuation on firms' operation decisions (Ren et al., 2022). However, most energy finance literature fails to provide convincing evidence of oil price fluctuation on the cost of debt, especially in underdeveloped countries. Accordingly, we supplement the relevant research and find that

³ We focus on the cost of public debt (bond) rather than the cost of bank debt for several reasons. Firstly, bond financing plays a critical role in firms' external financing sources (Wei et al., 2022) and its offering spread can proxy for the debt financing cost. Secondly, bondholders have limited access to confidential information and renegotiation power compared to private debtholders like banks. This makes bond prices more sensitive to a firm's underlying downside risks (Wang et al., 2021). Thirdly, detailed and loan data for companies are not available in China. Existing proxies for measuring the cost of bank debts have obvious shortcomings (Wang et al., 2019). Therefore, bond offering spread is a more suitable measurement to gauge the cost of debt.

oil price fluctuation may increase firms' financing costs.

Secondly, our paper contributes to the growing body of literature on the cost of debt (Chen, 2012; Liu et al., 2022). Previous research demonstrates that intra-firm conditions, such as firms' performance (Jiang, 2008), corporate governance (Bradley & Chen, 2011; Bliss & Gul, 2012), and information environment (Andrade et al., 2014; Bonsall & Miller, 2017; Gao et al., 2020) can affect debt financing cost. In addition, macro factors, such as policy uncertainty (Kaviani et al., 2020), transportation infrastructure (Wei et al., 2022), and national culture (Chui et al., 2016), also have an impact on bond prices. We contribute to the literature by exploring factors influencing debt financing cost.

The remainder of this study is organized as follows. In Section 2, we review the relevant literature on the debt financing cost and oil price fluctuations and develop the hypotheses. Section 3 provides a detailed description of our sample and variable construction. Section 4 presents baseline empirical results on the impact of oil price fluctuations on debt financing cost. Furthermore, Section 5 reports the results of our heterogeneity analyses and discusses how firm ownership and industry characteristics impact the bond market. In Section 6, we examine the asymmetric and nonlinear effects. Finally, Section 7 concludes the study and presents policy recommendations based on our findings.

2. Literature review and hypothesis development

2.1. The effects of oil price uncertainty

Prior studies have examined how oil price fluctuation affects macroeconomics and the financial market (Ferderer, 1996; Elder & Serletis, 2009; Bouri et al., 2017; Kocaaslan, 2019). For instance, Ferderer (1996) shows that oil price volatility helps forecast changes in the U.S. total output. Similarly, Kocaaslan (2019) finds that oil price fluctuation considerably drives up the unemployment rate in the American economy. Additionally, crude oil price fluctuation is negatively correlated with stock returns in both industrialized and emerging countries (Elder & Serletis, 2009; Bouri et al., 2017). A similar pattern also emerges in the bond market. According to Kang et al. (2014), increases in demand for oil in specific markets lead to a decrease in actual bond returns. Gormus et al. (2018) also demonstrate that oil and ethanol prices influence the high-yield bond market. Similarly, Apergis (2019) uses 14 countries' samples from 2000 to 2016 to examine the effect of oil prices on high-yield bond spreads and find the positive correlation between them.

From the micro-level, most existing studies focus on firms' operation decisions. Researchers explore the impact of oil price volatility on various aspects, including corporate payouts (Wong & Hasan, 2021), firm investment decision-making (Ratti et al., 2011), and firms' leverage (Fan et al., 2021). For instance, Phan et al. (2019) document that greater oil price fluctuation can lead to fewer corporate investment expenditures. Similarly, Zhang et al. (2020) demonstrate that there is a relationship between OPU and cash holdings that follows an inverted U-shape. Fan et al. (2021) investigate how oil price fluctuation affects firm debt leverage and discover a U-shaped link between them. Amin et al. (2023) state that oil price fluctuation contributes to uncertainty about future growth opportunities, leading to fewer innovation activities.

In sum, the previous studies have comprehensively explored the impact of crude oil price uncertainty on the stock market, bond market, and corporate operation decision-making in the context of developed economies. However, a dearth of studies works on how oil price fluctuation affects firms' financing costs, i.e., bond pricing in emerging countries. Developing countries are more sensitive to fluctuations in oil prices compared to developed countries due to their higher economic growth rates and greater reliance on energy-intensive production systems. More research is needed to understand the correlation between the cost of debt and oil price uncertainty in developing countries, and more research in this field is necessary. Our study aims to contribute to this body of knowledge by exploring the effects of uncertainty on debt financing cost.

2.2. Determinants of the cost of debt (bond offering spread)

The bond market is among the most important sources for firms to access finance (Myers, 2003); hence many financial studies have investigated what factors influence the bond credit spread (Boubakri & Ghouma, 2010; Gao et al., 2020). The majority of previous literature concentrates on the effect of intra-firm conditions on bond offering spread. As an example, Binsbergen et al. (2010) demonstrate that debtholders will impose a higher premium on bond issuers with worse performance. Moreover, some scholars explore the role of corporate governance on bond offering spread (Anderson et al., 2004; Bradley & Chen, 2011). In particular, debtholders will require a greater premium for companies with poor corporate governance because these firms are inclined to deteriorate their interests (Boubakri & Ghouma, 2010).

Additionally, many researchers pay attention to the connection between the information environment and bond pricing since debtholders would charge larger premiums to make up for the higher risk driven by information asymmetry (Yu, 2005; Gao et al., 2020). Besides, a poorer information environment would also narrow a bond's debtholders base by making a bond less attractive to own, thereby decreasing the bond's trading activity and liquidity (Gao et al., 2020), which would further increase the bond offering spread (Goldberg & Nozawa, 2021).

Recent studies have presented compelling evidence of a robust association between external environment and its debt financing cost. For example, Chui et al. (2016) show that cultural dimensions could mitigate debt financing cost. Furthermore, Bradley et al. (2016) demonstrate that policy uncertainty may positively affect the debt financing cost in the US. Wei et al. (2022) find that bond issuers affected by the HSR network experience lower financing costs. Nonetheless, oil price fluctuations have a potential impact on debt financing cost that is not well understood, despite it being a crucial external factor for businesses. We shed light on the connection between bond offering spread and oil price uncertainty to close this knowledge gap by showing that oil price uncertainty can drive up

bond offering spread.

2.3. Hypothesis development

As crude oil is a vital component of various production inputs, its price uncertainty could denote a significant uncertainty that may adversely influence the cost of production and service, the decision of investments, profitability, cash flow, and innovations, thus affecting firms' performance and default risk (Phan et al., 2020). According to Henriques and Sadorsky (2011), oil price uncertainty is responsible for delaying investments, which invariably results in lost opportunities for lucrative investments. Phan et al. (2020) state that oil price fluctuation is disruptive to firm performance and profitability. Bondholders may alter their claim on debts to compensate for elevated default risks caused by greater oil price uncertainty. Therefore, we can predict that oil price volatility may increase the debt financing cost. We propose our first hypothesis as follows:

Hypothesis 1. Oil price uncertainty may increase the cost of debt.

Specifically, oil price uncertainty can increase debt financing cost by increasing firms' default risks. Due to the major role of oil in firms' operations, its price uncertainty denotes a significant uncertainty for firms (Fan et al., 2021). Elevated uncertainty in oil prices can increase the value of delaying investment, causing firms to postpone their investments (Henriques & Sadorsky, 2011). However, any delay in firm investment may lead to losses in profitable investment opportunities and adversely affect firms' fundamentals, which may weaken firms' repayability (Phan et al., 2020). Moreover, as a source of uncertainty, increased oil price volatility may exacerbate the information asymmetry between bondholders and firms, which may increase default risks. Oil price fluctuations may appear to have a similar effect on consumer spending and consumption expenditure. As such, oil price uncertainty may result in fewer demands for firms' products or services, which may have a negative impact on the firm's fundamentals, resulting in higher default risks. Therefore, oil price uncertainty may increase firms' default risks, which are closely associated with debt financing cost. Under such circumstances, bondholders may demand a higher premium when they face greater oil price uncertainty. Since uncertainty in oil prices could raise the likelihood of defaults among businesses, we can anticipate that the cost of debt may increase as a result. We put forward our second hypothesis as follows:

Hypothesis 2. Oil price uncertainty can raise the cost of debt by increasing firms' default risks.

3. Data description and empirical strategy

3.1. Sample descriptions

Our sample comprises bonds issued by firms between 2008 and 2019.⁴ We collect 17,211 bonds from Wind Database, which includes enterprise bonds, corporate bonds, and medium-term notes. In line with similar studies, we exclude 12 bonds with missing data, 1141 bonds in the financial sector, and 122 non-fixed rate bonds since these bonds differ from standard bonds (Gao et al., 2020). Finally, we get a sample of 15,936 bonds issued by 3942 companies. The oil price data is retrieved from two websites, that are Chicago Board Options Exchange (CBOE) and West Texas Intermediate (WTI), and other financial and bond data is from the Wind Database. To mitigate the potential effect of outliers that could skew the results, the winsorization is performed for all continuous variables at their 1st and 99th percentiles.

3.2. The descriptions of main variables

3.2.1. Dependent variables

According to Gao et al. (2020), we generate two measures of bond offering spreads to proxy for debt financing cost. The first measure (*CS1*) is computed as follows:

$$CS1_{i,t} = CB_{i,t}^{Coupon} - CTB_i^{Coupon} \quad (1)$$

where, $CS1_{i,t}$ is the offering spread for bond i in time t . $CB_{i,t}^{Coupon}$ is the coupon rate for bond i issue in time t . CTB_i^{Coupon} is the coupon rate for the matched treasury bond issued at time t , which has similar maturity with bond i .

The second measure (*CS2*) is constructed for robustness check, which is defined as follows:

$$CS2_{i,t} = CB_{i,t}^{Yield} - CTB_i^{Yield} \quad (2)$$

where, $CS2_{i,t}$ is the offering spread for bond i at issuance time t . $CB_{i,t}^{Yield}$ is the yield for bond i at the first trading day t . CTB_i^{Yield} is the yield for matched treasury bond at the first trading day t , which has similar maturity to bond i .

⁴ Because the medium-term notes, a key element of the bond markets, were first issued in 2008, our sample period begins in that year.

3.2.2. Independent variables

Following the existing literature, we construct three measures of oil price uncertainty. Specifically, the first measure of oil price volatility (OVX) is defined as follows:

$$OVX_t = \frac{1}{N} \sum_n^{N} ovx_{t,n} \tag{3}$$

where, $ovx_{t,n}$ implies the daily crude oil volatility index on day n of year t , which is collected from the Chicago Board Options Exchange (CBOE). The crude oil price volatility index is a reliable indicator of oil price volatility since it may provide information on past or future oil prices.

We also use the standard deviation of oil price fluctuations to assess oil price uncertainty. Following the approach of Sadorsky (2008), which can be expressed as follows:

$$OPUSD_t = \sqrt{\frac{1}{N-1} \sum_{n=1}^N (r_{t,n} - E(r_{t,n}))^2} \cdot \sqrt{N} \tag{4}$$

where, N represents the number of trading days in a year t . $r_{t,n}$ present Brent daily oil price return in day n of year t . We calculate this value as 100 times the natural logarithm of the ratio of the oil price on day n to the oil price on day $n-1$.

As an additional robustness check, we also assess oil price uncertainty using the conditional variance from a GARCH model, following the approach of Wang et al. (2017) and Alaali (2020). The detailed construction procedure is as follows:

We first construct a GARCH (1,1) model:

$$r_t = \mu + \varepsilon_t \tag{5}$$

$$h_t^2 = \omega + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1}^2 \tag{6}$$

where, r_t represents daily oil prices return, μ is the average return, h_t^2 is the conditional variance, and ω is the constant term. ε_t denotes the residual return. We then average the daily conditional variance to calculate a third measure:

$$OPUCON_t = \frac{1}{N} \sum_{i=1}^N \hat{h}_t^2 \tag{7}$$

where, \hat{h}_t^2 is the predicted value from Eq. (6).

3.3. Empirical strategy

We estimate the following equation to explore whether oil price volatility affects debt financing cost:

$$Spread_{i,t} = \beta_0 + \beta_1 OPU_{i,t-1} + \delta_1 BondControl_{i,t} + \delta_2 OtherControl_{i,t-1} + \sigma_i + \varepsilon \tag{8}$$

where, i denotes bond, and t represents year. $Spread_{i,t}$ denotes the offering spread of bond i in year t gauged by *CSI*. β_0 denotes the constant variable. The primary independent variable (OPU_{t-1}) refers to oil price volatility in year $t-1$. In this formulation, the correlation between oil price uncertainty and the cost of debt is captured by β_1 . We anticipate that the sign of this variable will be positive, indicating that oil price uncertainty could raise the cost of debt.

We also incorporate several control variables in accordance with the prior research on the cost of debt. First, we take bond-level factors ($BondControl_{i,t}$) into account as these factors are closely related to bond offering spread, including bond maturity (*Term*), bond rating (*Rating*), and issue size (*Issuesize*).⁵ Second, we add some firm-level and macro-level variables ($OtherControl_{i,t-1}$), including size (*Size*), growth opportunity (*Growth*), return on assets (*ROA*), return on equity (*ROE*), firm's cash flow (*Cash*), firm's debt-to-asset ratio (*Leverage*), and the listed firm dummy variable (*List*) indicating whether firms are publicly traded. Finally, we use the economic policy uncertainty index (*EPU*) to consider other uncertainties. To account for the influence of the global financial crisis, we construct dummy variables (*GFC*). We include the GDP growth rate (*GDPG*) to control for macroeconomic growth. We also include firm-fixed effects (σ_i) to control for time-invariant characteristics specific to the firms. ε denote error term.⁶ Detailed and comprehensive definitions are included in Appendix A. We cluster robust standard errors at the firm level to control for within-firm serial correlations in the error

⁵ We use bond-issuance level data rather than the bond-trading year level data to study how oil price uncertainty affects bond offering spread (i.e., the cost of debt). In this sample, we have only one observation for each bond-issuance event, leading to bond-level variables are only available after bonds are issued, i.e., these bond-level variables do not have lag terms. Thus, we only control for bond-level variables in year t .

⁶ Following Wong and Hasan (2021), our analysis does not incorporate account for the year-fixed effects as each bond i in year t has the identical value of oil price uncertainty. Under such circumstances, the year-fixed effects could potentially absorb all explanatory capacity of the oil uncertainty variable.

term.

4. Empirical results

4.1. Description of main variables and descriptive statistics

To conduct the empirical analysis, we first provide summary statistics of the main variables, including oil price uncertainty, bond offering spread, and control variables, and display them in [Table 1](#).

The average bond offering spread, *CS1*, is 2.4492%, which has the same scale as [Wei et al. \(2022\)](#). However, the average bond offering spread in China is larger in comparison to its counterpart in the mature bond market ([Gao et al., 2020](#)). In addition, on average, *OVX (OPUSD)* is 33.9255 (1.5539).

4.2. Empirical results

To initiate the primary analysis, we utilize [Eq. \(8\)](#) to investigate whether oil price uncertainty influences debt financing cost. [Table 2](#) indicates the baseline regression results. Columns (1) and (3) include firm-fixed effects without adding control variables. The coefficient on *OVX* and *OPUSD* is 0.0144 and 0.1873 above the 1% significance level. In other columns, we account for all control variables for the regression. The coefficients on *OVX* and *OPUSD* remain significantly positive, which implies that oil price uncertainty increases debt financing cost. Moreover, our findings are also economically significant, with the coefficients at 0.0106 and 0.1590. It indicated that oil price uncertainty measured by *OVX (OPUSD)* experiences rises in a one-standard deviation, leading to an 8.6% (7.8%) drive-up in bond offering spread.

In sum, with the different measurements, our baseline regression result shows that increased oil price uncertainty leads to higher bond offering spreads. To be more specific, the benchmark analysis reveals that oil price uncertainty increases firms' financing costs, i. e., oil price uncertainty worsens firms' financing conditions, which confirms our predictions ([Hypothesis 1](#)).

4.3. Robustness checks

To strengthen the baseline results, we implement some robustness tests and address other potential problems with the benchmark analysis. First, we duplicate the regression in [Section 4.2](#) by replacing independent variables with alternative measurements (i.e., bond offering spread). We use *CS2* to replace *CS1* as the dependent variable. Results using alternative dependent variables (bond offering spread) are displayed in the first two columns of [Table 3](#). As we can see, the significantly positive coefficients of *OVX (OPUSD)* demonstrate that the baseline results still hold with different measurements.

In addition, we regress [Eq. \(8\)](#) using an alternative metric of the independent variable (i.e., oil price uncertainty). We use *OPUCON* as a proxy for the independent variable. As shown, the coefficient of *OPUCON* is significantly positive, implying that the baseline results are valid after we use a different variable to proxy for oil price fluctuation.

In sum, the baseline results are robust to different metrics of independent and dependent variables. We are convinced that the fluctuating oil price increases the cost of debt.

4.4. Instrument variable

There may be a concern that our findings may be biased because of omitted variables (e.g., some unobserved variables, including unstable political environment, unstable financial markets, or unstable economic conditions). To resolve this problem, we perform a two-stage least squares regression (2SLS). Then, we employ the average geopolitical risk (*GPR_AVR*) of the two largest oil consumers and oil producers as an instrument. According to [Hasan et al. \(2022\)](#), *GPR_AVR* is a good instrumental variable. On the one hand, geopolitical uncertainties are closely associated with oil price volatility. On the other hand, geopolitical uncertainty does not directly affect bond offering spreads, rendering our instrumental variable appropriate ([Noguera-Santaella, 2016](#)).

Using *GPR_AVR*, we then conduct 2SLS regression to further address the concerns about the interference of unobserved confounders. In the first stage, we regress *OVX* or *OPUSD* on *GPR_AVR* and then get the predicted variable of *OVX* or *OPUSD* (*P_OVX* or *P_OPUSD*). Then we regress *CS1* on *P_OVX* or *P_OPUSD*. The results of 2SLS regression are displayed in [Table 4](#).

Columns (1) and (2) present the outcomes of the first stage, where the coefficient on *GPR_AVR* is positive, implying a significant connection. The Kleibergen-Paap F-statistics are 63.21 and 53.14, denoting no weak IV problem, which indicates that the instrument variable does not have a weak-instrument problem ([Gan et al., 2022](#)). Columns (3) and (4) illustrate the results of the second-stage regression. In line with primary results, the coefficient on *P_OVX* or *P_OPUSD* remains significant and positive, signifying that endogeneity is not a concern in our findings.

4.5. Potential mechanism

In the previous subsection, we document that the cost of debt can be disrupted by oil price volatility, which drives up firms' financing costs. These empirical findings hold up well to various measurements of the bond offering spread and oil price uncertainty. A remaining question is how oil price uncertainty influences debt financing cost.

In [Section 2](#), we have discussed that elevated uncertainty in oil prices may increase debt financing cost by raising the default risks of

Table 1
Summary statistics.

	(1)	(2)	(3)	(4)	(5)	(6)
	Obs.	Mean	SD	Min	P50	Max
<i>CS1</i>	15,936	2.4492	0.7518	1.1658	2.3591	4.1943
<i>CS2</i>	15,936	2.6687	0.4181	0.9555	2.6346	4.3946
<i>OVX</i>	15,936	33.9255	8.1597	22.4605	32.1725	52.0080
<i>OPUSD</i>	15,936	1.5539	0.4922	0.9111	1.3797	2.7892
<i>OPUCON</i>	15,936	4.9707	2.9227	1.7312	3.3263	14.4079
<i>Term</i>	15,936	5.5038	2.0537	1.5000	5.0000	20.0000
<i>Rating</i>	15,936	4.2853	1.3558	1.0000	4.0000	6.0000
<i>Issuesize</i>	15,936	2.3821	0.6385	1.0296	2.3979	4.3944
<i>Size</i>	15,936	5.9824	1.3947	0.5459	5.7172	11.5691
<i>ROA</i>	15,936	3.6148	2.9265	-0.7417	2.8401	15.3764
<i>ROE</i>	15,936	5.0601	6.1230	-0.3901	3.2877	27.9784
<i>Cash</i>	15,936	0.5348	0.5943	0.0412	0.3542	3.8381
<i>Leverage</i>	15,936	57.6539	14.6901	21.0779	59.1842	86.3337
<i>List</i>	15,936	0.1632	0.3695	0.0000	0.0000	1.0000
<i>EPU</i>	15,936	184.5153	98.2713	92.1000	129.3167	363.3667
<i>GFC</i>	15,936	0.0326	0.1775	0.0000	0.0000	1.0000
<i>GDPG</i>	15,936	7.1993	1.0345	6.1000	6.9000	10.6000

This table presents the summary statistics for variables used in this paper. The sample includes 15,936 bond-year observations over the sample period running from 2008 to 2019. All continuous variables are winsorized at 1% and 99%, respectively. * **, * *, and * indicate significance at 1%, 5%, and 10% levels, respectively.

Table 2
Basic regression results.

	(1)	(2)	(3)	(4)
Variables	<i>CS1</i>	<i>CS1</i>	<i>CS1</i>	<i>CS1</i>
<i>OVX</i>	0.0144*** (0.0010)	0.0106*** (0.0010)		
<i>OPUSD</i>			0.1873*** (0.0174)	0.1590*** (0.0173)
<i>Term</i>		-0.0055 (0.0037)		-0.0052 (0.0037)
<i>Rating</i>		-0.1869*** (0.0211)		-0.1884*** (0.0212)
<i>Issuesize</i>		0.0012 (0.0146)		0.0030 (0.0146)
<i>Size</i>		-0.2540*** (0.0377)		-0.2663*** (0.0380)
<i>Leverage</i>		0.0002 (0.0016)		0.0003 (0.0016)
<i>ROA</i>		0.0037 (0.0091)		0.0032 (0.0091)
<i>ROE</i>		-0.0120*** (0.0038)		-0.0116*** (0.0038)
<i>Cash</i>		-0.1164*** (0.0272)		-0.1117*** (0.0273)
<i>List</i>		-0.3395 (0.3464)		-0.3401 (0.3388)
<i>EPU</i>		0.0005*** (0.0001)		0.0006*** (0.0001)
<i>GFC</i>		0.2957*** (0.0469)		0.2963*** (0.0482)
<i>GDPG</i>		0.0676*** (0.0129)		0.0783*** (0.0131)
Firm FE	Yes	Yes	Yes	Yes
Observations	15,936	15,936	15,936	15,936
Adjusted R ²	0.6590	0.7121	0.6515	0.7099

This table shows the regression results on the effect of oil price uncertainty on the cost of debt. All variables are defined in Appendix A. We do not add control variables in Columns 1 and 3. Control variables and the fixed effects of firm are included in Columns 2 and 4. Standard errors are reported in parentheses, adjusting for clustering at the firm level. * **, * *, and * indicate significance at 1%, 5%, and 10% levels, respectively.

Table 3
Robustness checks.

	(1)	(2)	(3)
Variables	CS2	CS2	CS1
OVX	0.0101 ^{***} (0.0011)		
OPUSD		0.1967 ^{***} (0.0199)	
OPUCON			0.0243 ^{***} (0.0032)
Control	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Observations	15,936	15,936	15,936
Adjusted R ²	0.7032	0.7046	0.7079

This table reports the robustness results. Columns 1 and 2 report the results of using alternative measure of bond offering spread. Column 3 shows the results of using alternative measure of oil price uncertainty. All variables are defined in [Appendix A](#). To save space, we do not report coefficients on control variables and constants. Standard errors are reported in parentheses, adjusting for clustering at the firm level. ^{***}, ^{**}, and ^{*} indicate significance at 1%, 5%, and 10% levels, respectively.

Table 4
Endogeneity test.

	(1)	(2)	(3)	(4)
Stage	First stage		Second stage	
Variables	OVX	OPUSD	CS1	CS1
GPR_AVR	2.9455 ^{***} (0.2780)	0.0625 ^{***} (0.0168)		
OVX			0.0090 [*] (0.0049)	
OPUSD				0.4222 [*] (0.2484)
Control	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	15,936	15,936	15,936	15,936
Adjusted R ²	0.4027	0.4548	0.2005	0.1500

This table shows the results of endogeneity test. Following Hasan et al. (2021), we use the yearly average geopolitical risk (GPR_AVR) of USA, China, Saudi Arabia and Russia as an instrument. Columns 1 and 2 are the results of the first stage. Columns 3 and 4 are the results of the second stage. All variables are defined in [Appendix A](#). Firm-fixed effects are included in all regressions. Standard errors are reported in parentheses, adjusting for clustering at the firm level. ^{***}, ^{**}, and ^{*} indicate significance at 1%, 5%, and 10% levels, respectively.

Table 5
Mechanism analysis.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Default1	CS1	Default1	CS1	Default2	CS1	Default2	CS1
OVX	0.0003 ^{***} (0.0001)	0.0105 ^{***} (0.0007)			-0.0325 ^{***} (0.0120)	0.0104 ^{***} (0.0010)		
OPUSD			0.0045 ^{***} (0.0017)	0.1583 ^{***} (0.0121)			-0.6141 ^{***} (0.2170)	0.1558 ^{***} (0.0173)
Default1		0.1576 [*] (0.0807)		0.1625 ^{**} (0.0816)				
Default2						-0.0052 ^{**} (0.0022)		-0.0053 ^{**} (0.0023)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,936	15,936	15,936	15,936	15,936	15,936	15,936	15,936
Adjusted R ²	0.5744	0.7122	0.5744	0.7100	0.7184	0.7126	0.7185	0.7105

This table shows the results of the mechanism of how oil price uncertainty affects the cost of debt. All variables are defined in [Appendix A](#). To save space, we do not report coefficients on control variables and constants. Standard errors are reported in parentheses, adjusting for clustering at the firm level. ^{***}, ^{**}, and ^{*} indicate significance at 1%, 5%, and 10% levels, respectively.

bond issuers. Following [Chen et al. \(2022\)](#), we create two measures of firms' default risks, including (1) a dummy variable (*Default1*), which is one for bond issuers' earnings before interest and taxes are negative; zero, otherwise. (2) the ratio of earnings before interest and taxes on assets of bond issuers (*Default2*). Accordingly, issuers with greater *Default1* or lower *Default2* have greater default risks.

In line with [Baron and Kenny \(1986\)](#), we use a two-step method to examine the mechanisms of oil price volatility on debt financing cost. More specifically, we estimate [Eq. \(8\)](#) and the following equations:

$$\text{Mechanism}_{i,t} = \beta_0 + \alpha_1 \text{OPU}_{i,t-1} + \lambda_1 \text{BondControl}_{i,t} + \lambda_2 \text{OtherControl}_{i,t-1} + \sigma_i + \varepsilon \quad (9)$$

$$\text{Spread}_{i,t} = \beta'_0 + \beta'_1 \text{OPU}_{i,t-1} + \beta'_2 \text{Mechanism}_{i,t-1} + \delta'_1 \text{BondControl}_{i,t} + \delta'_2 \text{OtherControl}_{i,t-1} + \sigma_i + \varepsilon \quad (10)$$

where, *Mechanism* is the mechanism variable, i.e., *Default1* or *Default2*. Other variables are defined in [Eq. \(8\)](#). This mechanism holds when the coefficient on *OPU* in [Eq. \(9\)](#), and the coefficient on mechanism variable in [Eq. \(10\)](#) are both significant.

Regression results of mechanism are shown in [Table 5](#). Odd columns show the results of [Eq. \(9\)](#). The coefficient on *OPU* is statistically positive (negative) when *Default1* (*Default2*) is the dependent variable, indicating that oil price volatility is associated with heightened default risk. Even columns present the results of [Eq. \(10\)](#). As documented, the coefficient corresponding to *Default1* (*Default2*) is significantly positive (negative), suggesting that bond issuers with greater default risks face higher financing costs, i.e., their default risk leads to wider bond offering spreads. Thus, oil price uncertainty may contribute to an increase in default risk, ultimately leading to higher costs of debt, thereby supporting [Hypothesis 2](#).

5. The analysis of heterogeneous effects

5.1. Firm ownership

In China, firms are divided into SOE (state-owned) and non-SOE firms based on their equity. SOE enterprises have an implicit guarantee that could lower default risks and thus decrease the cost of debt ([DeWenter & Malatesta, 2001](#)). As debtholders and shareholders claim ownership of the same underlying asset, state-owned firms may suffer less from oil price fluctuation. Accordingly, we conclude that SOE-issued bonds should be less pronounced for bonds issued by SOEs.

To ascertain whether the positive effect varies across issuers' ownership, we create a dummy variable (*SOE*) to measure state ownership, which is defined as one for bonds issued by SOEs; otherwise, it equals zero. We then modify [Eq. \(8\)](#) by adding *SOE* and the interaction term of *OVX* (*OPUSD*) and *SOE* to explore whether state-owned status can alleviate the adverse impact of oil price fluctuations on the cost of debt.

The interaction term (*OVX*×*SOE* or *OPUSD*×*SOE*) captures how state ownership moderates the impact of oil price fluctuation on debt financing cost. According to our analysis, the coefficient on *OPU*×*SOE* should exhibit a negative sign. Our finding indicates that the detrimental impact of oil price uncertainty on debt financing cost can be attenuated for issuers that are SOEs.

[Table 6](#) documents the heterogeneity analysis of state ownership. In Columns 1 and 2, we use *OVX* and *OPUSD* to gauge oil price volatility, respectively. As anticipated, the interaction term displays statistically significant and negative, indicating that bonds issued by SOEs affect less by oil price uncertainty, which provides convincing evidence to support our proposition that issuers' ownership status alleviates the adverse impact of oil price fluctuation on debt financing cost.

5.2. Oil usage intensity

Firms with higher energy use intensity are often viewed as more vulnerable to changes in energy prices, as they typically have higher energy costs as a percentage of their total costs. These firms have a greater dependence on energy inputs in their operations, which makes them more susceptible to changes in energy prices. Oil usage intensity varies across industries ([Narayan & Nasiri, 2020](#)). Sensitivity to energy prices can transform into greater financial risk for these firms. Investors may perceive them as less able to withstand economic downturns or other sources of uncertainty. Thus, it can lead to wider spreads for these firms, as investors demand a higher risk premium for holding their bonds. Therefore, we expect that industries' oil usage intensity could exacerbate the positive effect of oil price fluctuation on the debt financing cost.

To examine whether industries' oil intensity and sensitivity could exacerbate the adverse effect of oil price fluctuation on debt financing cost, we first identify whether bond issuers are in energy-related industries and construct a new dummy variable *ERI*, to serve as a proxy for oil usage-intensive industries.⁷ Specifically, the energy-related industries' dummy variable, *ERI*, equals 1 for firms from energy-related industries and zero otherwise. We then modify [Eq. \(8\)](#) by adding *ERI* and the interaction term of *OVX* (*OPUSD*) and *ERI* to explore the potential impact of energy usage intensity on the association between oil price volatility and debt financing cost. We predict that the coefficient on *OVX*×*ERI* (*OPUSD*×*ERI*) should be positive, suggesting that energy-related industries can exacerbate the positive effect of oil price fluctuation on debt financing cost.

The heterogeneity analysis based on whether firms are in the oil-usage-intensive industries is displayed in [Table 7](#). Columns 1 and 2

⁷ Following [Bouri et al. \(2017\)](#), we define following industries as energy-related ones: Energy industry, material industry, consumer discretionary industry, and public utilities industries.

Table 6
Heterogeneity analysis: Ownership.

Variables	(1)	(2)
	CSI	CSI
OVX	0.0152*** (0.0025)	
OPUSD		0.2634*** (0.0409)
OVX×SOE	-0.0056** (0.0026)	
OPUSD×SOE		-0.1273*** (0.0440)
Control	Yes	Yes
Firm FE	Yes	Yes
Observations	15,936	15,936
Adjusted R ²	0.7124	0.7107

This table shows the heterogeneity analysis of state ownership. Columns 1 and 2 show the moderate effect of state ownership on the relationship between oil price uncertainty and the cost of debt, using OVX and OPUSD as a measure of oil price uncertainty. All variables are defined in Appendix A. Firm-fixed effects are included in all regressions. To save space, we do not report coefficients on SOE, control variables and constants. Standard errors are clustered at the firm level. Standard errors are in parentheses. ***, **, * and * indicate significance at 1%, 5%, and 10% levels, respectively.

use OVX and OPUSD to gauge oil price uncertainty. The coefficient on OVX×ERI (OPUSD×ERI) is statistically significantly positive, indicating that bonds issued by firms from energy-related industries affect more, i.e., issuers from the energy-related industries suffer greater financing costs. These results confirm our proposition that energy usage intensity could exacerbate the positive effect of uncertainty on debt financing cost.

6. Further analysis

6.1. The asymmetric effect of oil price uncertainty

In the previous section, we examined how oil price uncertainty influences bond offering spread. As has been widely documented, the asymmetric effect of OPU is prevalent in the financial market and firms' operation behaviors in both mature and emerging countries (Xiao et al., 2018). There may be an asymmetric effect of oil price uncertainty on debt financing cost, as bond issuers and stockholders are claimed for the same underlying assets (Gao et al., 2020). The discrepancy between the real option to wait and the expected investment returns declines when negative oil price volatility occurs. Consequently, firms incur lesser losses in profitable investments and have reduced default risks in times of negative oil price volatility. Conversely, in positive oil price volatility, the opposite trend ensues. Given the foregoing analysis, oil price uncertainty resulting from positive (negative) returns to oil prices could have a more pronounced (less pronounced) impact on debt financing cost.

To estimate the asymmetrical impact of oil price volatility on debt financing cost, we generate measures of positive and negative oil price fluctuations. Following previous studies (Farago & Tédongap, 2018; Xiao et al., 2018), oil price fluctuation is decomposed into positive oil price uncertainty (denoted as $OPU_t^{Positive}$) as well as negative oil price uncertainty (denoted as $OPU_t^{Negative}$). Based on Eq. (11), we generate two variables as proxies for the positive and negative uncertainty of oil prices.

$$\begin{aligned}
 OPU_t^{Positive} &= \max\{OPU_t^{Positive}, 0\} \Rightarrow OPU_t^{Positive} = \begin{cases} OPU_t & \text{if } r_t > 0 \\ 0 & \text{otherwise} \end{cases} \\
 OPU_t^{Negative} &= \max\{OPU_t^{Negative}, 0\} \Rightarrow OPU_t^{Negative} = \begin{cases} OPU_t & \text{if } r_t < 0 \\ 0 & \text{otherwise} \end{cases}
 \end{aligned}
 \tag{11}$$

where, $OPU_t^{Positive}$ denotes positive uncertainty of oil price, while $OPU_t^{Negative}$ stands for negative uncertainty of oil price. r_t indicates oil returns.

Following Maghyereh & Abdoh (2020), we employ the following empirical equation to explore the asymmetric effect:

$$\begin{aligned}
 Spread_{i,t} &= \beta_0 + \beta_1 OPU_{i,t-1}^{Positive} + \beta_2 OPU_{i,t-1}^{Negative} + \delta_1 BondControl_{i,t} \\
 &+ \delta_2 OtherControl_{i,t-1} + \sigma_i + \varepsilon
 \end{aligned}
 \tag{12}$$

where, $OPU_{i,t-1}^{Positive}$ and $OPU_{i,t-1}^{Negative}$ denote positive uncertainty and negative uncertainty of oil price, respectively. This equation also considers the control variables from Eq. (8). We also account for firm-fixed effects and cluster at the firm level. β_1 and β_2 depict the asymmetric impact of uncertainty for oil price on debt financing cost. If β_1 is significantly different from β_2 , it implies the asymmetric impact of oil price fluctuation on debt financing cost exists; otherwise, there has no asymmetric effect.

Table 7
Heterogeneity analysis: Oil usage intensity.

	(1)	(2)
Variables	CSI	CSI
OVX	0.0089*** (0.0010)	
OPUSD		0.1172*** (0.0170)
OVX×ERI	0.0067*** (0.0015)	
OPUSD×ERI		0.1632*** (0.0257)
Control	Yes	Yes
Firm FE	Yes	Yes
Observations	15,936	15,936
Adjusted R ²	0.7123	0.7101

This table shows the heterogeneity analysis of oil usage intensity. Columns 1 and 2 show the moderate effect of oil usage intensity on the relationship between oil price uncertainty and the cost of debt, using OVX and OPUSD as a measure of oil price uncertainty. To save space, we do not report coefficients on ERI, control variables, and constants. All variables are defined in Appendix A. Firm-fixed effects are included in all regressions. Standard errors are clustered at the firm level. Standard errors are in parentheses. ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively.

As displayed in Table 8, the results are estimated using Model (12). Under all measurements of oil price uncertainty, the coefficient on $OVX^{Positive}$ or $OPUSD^{Positive}$ ($OVX^{Negative}$ or $OPUSD^{Negative}$) is statistically significantly positive in each column. Moreover, the coefficient on $OVX^{Positive}$ or $OPUSD^{Positive}$ is greater than the coefficient on $OVX^{Negative}$ or $OPUSD^{Negative}$, which preliminarily supports our prediction that oil price fluctuation has an asymmetric impact on debt financing cost. To be more rigorous, we perform a Wald test to test this asymmetric effect. The results indicate that the debt financing cost is asymmetrically affected by oil price volatility. The greater (smaller) effect of positive (negative) oil price fluctuation on debt financing cost can be attributed to debtholders being more (less) sensitive to bad (good) news as positive (negative) oil price fluctuation is regarded as bad (good) (Xiao et al., 2018).

6.2. Nonlinear effect of oil price uncertainty

A growing literature shows that oil price fluctuation has a nonlinear effect on various firm activities. For example, Henriques and Sadorsky (2011) reveal that oil price uncertainty and firm investment are correlated in a U-shaped manner. Similarly, Zhang et al. (2020) demonstrate that firms' cash holdings increase up to a certain point with oil price uncertainty but then decrease. Oil price

Table 8
Asymmetric effect of oil price uncertainty.

	(1)	(2)
Variables	CSI	CSI
$OVX^{positive}$	0.0139*** (0.0010)	
$OVX^{negative}$	0.0072*** (0.0015)	
$OPUSD^{positive}$		0.1632*** (0.0175)
$OPUSD^{negative}$		0.0966*** (0.0281)
Control	Yes	Yes
Firm FE	Yes	Yes
Observations	15,936	15,936
Adjusted R ²	0.7131	0.7118

This table shows asymmetric effect of oil price uncertainty on the cost of debt. Column 1 shows the result of using OVX as the proxy for oil price uncertainty ($OVX^{positive}$ and $OVX^{negative}$). Column 2 shows the result of using OPUSD as the proxy for oil price uncertainty ($OPUSD^{positive}$ and $OPUSD^{negative}$). All variables are defined in Appendix A. Firm-fixed effects are included in all regressions. To save space, we do not report coefficients on control variables and constants. Standard errors are clustered at the firm level. Standard errors are in parentheses. ***, **, and *, indicate significance at 1%, 5%, and 10% levels, respectively.

fluctuation and debt leverage are also associated in a U-shaped manner by Fan et al. (2021). Taking these findings into account, we hypothesize that oil price fluctuation may exhibit a non-linear effect on the debt financing cost. We estimate the following equation in order to investigate it:

$$\begin{aligned} Spread_{i,t} = & \beta_0 + \beta_1 OPU_{i,t-1} + \beta_2 OPU_{i,t-1}^2 + \delta_1 BondControl_{i,t} \\ & + \delta_2 OtherControl_{i,t-1} + \sigma_i + \varepsilon \end{aligned} \quad (13)$$

where, $OPU_{i,t-1}^2$ is the squared term of oil price fluctuation. Others are defined in baseline model. The estimated regression results are documented in Table 9.

The first two columns present the results using *OVX* and *OPUSD* as the proxy for oil price fluctuation, respectively. The coefficient corresponding to OVX^2 or $OPUSD^2$ is significantly negative, indicating a nonlinear impact of oil price uncertainty on debt financing cost. According to our results, we observe a non-linear link between oil price fluctuation and the debt financing cost, characterized by an inverted U-shape, which is consistent with the strategic growth options theory. It suggests that firms may choose to invest when uncertainty levels reach a certain threshold (Henriques & Sadorsky, 2011). Accordingly, firms may benefit from increased investment activities, leading to better fundamentals and repayability. Therefore, this adverse effect of oil price volatility on the debt financing cost may occur.

7. Conclusion and policy implications

We examine the effect of oil price uncertainty on the cost of debt. We begin by analyzing bonds issued by Chinese firms and use regression analysis to explore the impact of oil price fluctuation on debt financing cost. It is suggested that oil price uncertainty can increase bond offering spread, indicating an increase in debt costs. This result still holds when we use an alternative proxy for the bond offering spread or oil price uncertainty and conduct an endogeneity test.

We then test the mechanism of oil price fluctuation on the debt financing cost. The analysis demonstrates that the adverse impact of oil price fluctuation can increase default risks and thus can increase bond offering spread. This finding suggests that this effect is due to increased default risks induced by oil price fluctuation. Additionally, the detrimental effect of oil price uncertainty on debt financing cost is more pronounced for non-SOEs or energy-related industries. Moreover, we observe an asymmetric impact of oil price volatility on the cost of debt, with a stronger impact of positive uncertainty than negative one. Finally, we find the nonlinear effect of oil price volatility on debt financing cost, i.e., an inverted U-shaped link.

Our work expands the field of the pricing of firms' financing costs by showing that oil price fluctuation contributes to the increasing debt financing cost, which opens up new paths for further investigation into the effects of uncertainty on the cost of capital or equity. Moreover, the empirical findings also provide implications for policymakers, bond issuers, and investors. First, policymakers may have some insights from our study. Given our findings that oil price fluctuation may increase the cost of debt by increasing default risks, policymakers should implement several policies on oil supply or firms' financing costs to mitigate this adverse effect caused by oil price uncertainty. Moreover, governments should implement policies that stabilize oil prices and reduce uncertainty in the market. For instance, governments can implement strategic reserve management, price controls, or increased investment in alternative energy sources. Additionally, governments may need to provide credit support to companies and industries that are most vulnerable to oil price volatility, the transportation and manufacturing sectors, or non-SOEs, based on our findings that oil price fluctuation can increase the debt financing cost by increasing default risks. Second, bond issuers may need to be more transparent about the potential risks associated with their investments, including the effect of fluctuations on their financial performance. More important, issuers should adopt better risk management strategies, such as hedging or diversification, to mitigate the impact of oil price fluctuation on their bond offerings and default risk. Thirdly, our findings may also contribute to investors. Investors may need to conduct more thorough due diligence on bond issuers to assess their exposure to oil price risk and the effectiveness of their risk management strategies. Investors should incorporate the risk of oil price uncertainty into bond pricing models.

CRedit authorship contribution statement

Tian Gan: Methodology, Data curation, Formal analysis, Visualization. **Yan Jiang:** Project administration, Investigation, Validation. **Xi Wu:** Project administration, Conceptualization, Methodology, Formal analysis, Investigation, Supervision, Writing - review & editing. **Mingxin Zhang:** Investigation, Formal analysis, Funding acquisition.

Declaration of Competing Interest

None.

Data Availability

Data will be made available on request.

Table 9
Nonlinear effect of price uncertainty.

Variables	(1)	(2)
	CS1	CS1
OVX	0.1827*** (0.0173)	
OVX ²	-0.0025*** (0.0003)	
OPUSD		2.2247*** (0.2734)
OPUSD ²		-0.6290*** (0.0827)
Control	Yes	Yes
Firm FE	Yes	Yes
Observations	15,936	15,936
Adjusted R ²	0.7183	0.7143

This table shows the nonlinear effect of oil price uncertainty on the cost of debt. Columns 1 and 2 show the result of using *OVX* and *OPUSD* as the proxy for oil price uncertainty, respectively. All variables are defined in Appendix A. Firm-fixed effects are included in all regressions. To save space, we do not report coefficients on control variables and constants. Standard errors are clustered at the firm level. Standard errors are in parentheses. ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively.

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Appendix A. Definitions

Variables	Definitions
<i>CS1</i>	The difference between the coupon rate of the bond and the comparable Treasury Bond with equivalent duration at the bond issue date
<i>CS2</i>	The difference between the yield of a bond on the first trading day and the yield of a comparable Treasury Bond with an equivalent duration
<i>OVX</i>	Following Fan et al. (2021), we calculate the <i>OVX</i> for a given year by taking the average daily <i>OVX</i> index
<i>OPUSD</i>	Following Sadorsky (2008) and Henriques and Sadorsky (2011), our second measure is computed by the standard deviation of oil price changes
<i>OPUCON</i>	The third measure of oil price uncertainty is computed by the conditional variance from a GARCH model
<i>OVX^{Positive}</i>	Annual oil price volatility (<i>OVX</i>) for positive oil returns for each bond issuer in a given year
<i>OVX^{Negative}</i>	Annual oil price volatility (<i>OVX</i>) for negative oil returns for each bond issuer in a given year
<i>OPUSD^{Positive}</i>	Annual oil price volatility (<i>OPUSD</i>) for positive oil returns for each bond issuer in a given year
<i>OPUSD^{Negative}</i>	Annual oil price volatility (<i>OPUSD</i>) for negative oil returns for each bond issuer in a given year
<i>Term</i>	Years to maturity of a bond
<i>Rating</i>	An ordinal number ranging from 0 for A- bonds to 6 for AAA bonds
<i>Issuesize</i>	The total amount of bonds issued
<i>Size</i>	Natural logarithm of a firm's total assets
<i>Growth</i>	The operating income growth rate
<i>ROA</i>	The ratio of return to total assets
<i>ROE</i>	The ratio of return to equity
<i>Cash</i>	The ratio of the sum of the company's net profit and the current year's depreciation to the company's total assets
<i>Leverage</i>	The debt-to-asset ratio of a firm
<i>List</i>	A dummy variable equals 1 if firms are listed in the stock market and 0 otherwise
<i>EPU</i>	Economic policy uncertainty index (Baker, Bloom, & Davis, 2016)
<i>GFC</i>	Global Financial Crisis dummy variable, which equals to one at 2008–2009
<i>GDPG</i>	The GDP growth rate
<i>SOE</i>	A dummy variable, which equals one for the bonds issued by state-owned enterprises, and 0 otherwise
<i>ERI</i>	A dummy variable equals one for the bonds issued by firms from energy-related industries and 0 otherwise
<i>Default1</i>	A dummy variable, which equals one for bond issuers' earnings before interest and taxes are negative; zero, otherwise
<i>Default2</i>	The ratio of earnings before interest and taxes on assets of bond issuers

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