

Article

Financial Flexibility, Environmental Uncertainty, and Sustainable Development Performance of China's Energy Enterprises: An Empirical Test Based on an Inverted U-Shaped Relationship

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Abstract

China's economy has entered a new stage of high-quality development, and the sustainable development of enterprises has become the core task. Energy enterprises, as the strategic pillars of the country, are facing multiple challenges such as economic cycles, green transformation, and environmental uncertainty. Financial flexibility is crucial for the stable operation and sustainable development of these enterprises. This study selects energy enterprises listed on the Shanghai and Shenzhen Stock Exchanges from 2019 to 2023 as samples. Based on resource-based, agency and contingency theories, it builds a sustainable development performance evaluation system in terms of financial and environmental, social, and governance (ESG) dimensions. This study employs a panel fixed-effects model to empirically examine the nonlinear impact of financial flexibility on sustainable development performance and the moderating role of environmental uncertainty. The research findings are as follows: (1) There is a significant inverted U-shaped relationship between financial flexibility and the sustainable development performance of energy enterprises. Moderate reserves are conducive to improving performance, while excessive reserves have an inhibitory effect. (2) Environmental uncertainty amplifies the inverted-U-shaped impact of financial flexibility on sustainable development performance. (3) Heterogeneity analysis shows that this effect is more prominent in state-owned enterprises, enterprises in the central and western regions, and traditional energy enterprises. The conclusions of this paper provide empirical evidence and references for energy enterprises to optimize their financial strategies, cope with uncertainties, and achieve sustainable development.

Keywords: China's energy enterprises; financial flexibility; environmental uncertainty; sustainable development performance; inverted U-shaped relationship



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1. Introduction

1.1. Background and Literature Review

Against the backdrop of changes in the global economic and political landscape, firms face an unprecedented level of environmental uncertainty. How to survive and achieve long-term development in such a volatile environment has become a central issue in strategic management [1]. China's "dual carbon" goals require firms to shift toward green and low-carbon development. In addition, in 2024, the Ministry of Finance issued

the Corporate Sustainability Disclosure Standards—Basic Standards (Trial), which aim to guide capital toward more effective allocation in sustainable fields [2].

Financial flexibility refers to a firm's ability to obtain and allocate financial resources at relatively low cost in order to respond to future uncertainty and seize investment opportunities [3]. It is regarded as a key financial capability that helps firms manage risks and maintain strategic initiative. In China's capital market, firms face strong constraints on equity refinancing. Therefore, they mainly build financial flexibility by holding excess cash and maintaining low leverage [4]. Existing studies have widely examined the economic consequences of financial flexibility. Some studies confirm its positive value. For example, financial flexibility helps firms seize investment opportunities and smooth investment fluctuations under uncertain conditions [5]. It can also enhance firm value through precautionary motives [6]. However, other studies point out its potential costs. Excessive financial flexibility may lead to managerial overinvestment or slack, thereby damaging firm value [7]. Regarding firm value, some research shows that financial flexibility can effectively reduce the negative impact of adverse market conditions on corporate finance and significantly improve firm value [8]. However, financial flexibility and firm performance may also have an inverted U-shaped relationship. That is, firm performance first increases and then decreases as financial flexibility rises [9].

Sustainable development is a long-term development model. It aims to maintain a balanced and harmonious relationship among economic, social, and ecological interests under a set of institutional arrangements [10]. Existing studies on the determinants of sustainable development performance have mainly focused on corporate innovation [11,12] and corporate management [13,14]. However, few studies have examined the mechanism through which financial flexibility affects the sustainable development performance of energy enterprises. This is especially true from the perspectives of cash flow management and resource allocation. The Sustainable Development Goals (SDGs) emphasize the need to decouple economic growth from environmental pollution. They also focus on sustainable production, consumption, and job creation [15]. Energy enterprises usually face high capital demand and strong pressure for low-carbon transformation. Therefore, this study builds a comprehensive framework covering finance, environment, society, and governance to evaluate sustainable development performance. It further examines the relationship between sustainable development performance and financial flexibility.

1.2. Research Significance

Although relevant research has yielded rich results, there is still room for expansion. First, in terms of research perspective, most literature focuses on the impact of financial flexibility on traditional financial performance, but rarely places it within the ESG integration framework to explore its mechanism of action on integrated sustainable development performance that combines financial and non-financial dimensions. Compared with a single financial indicator or a single ESG score, multi-objective sustainable development performance provides a broader assessment. It considers both a firm's financial fundamentals and the environmental, social, and governance requirements that are specific to Chinese energy enterprises. It also places new constraints on how firms allocate their resources.

Second, in terms of research context, the existing literature mostly uses manufacturing industries as samples [16,17], while research on this industry, which has strong cycles, high capital intensity, and significant policy constraints, is relatively insufficient. The sustainable development performance of energy enterprises is affected not only by internal financial decisions but also by strong shocks from external environmental uncertainty [18]. Environmental uncertainty may influence how financial flexibility works. However, few studies have examined its boundary moderating role. Third, in terms of the mechanism

of action, the impact of financial flexibility on sustainable development performance may have nonlinear thresholds, but relevant empirical tests, especially in specific industries, are not yet sufficient.

Based on the above analysis, this study selects Chinese Shanghai and Shenzhen A-share energy industry listed companies from 2019 to 2023 as sample to answer the following core questions: How does financial flexibility affect the sustainable development performance of energy enterprises? Is there a nonlinear relationship between the two? Does external environmental uncertainty regulate this relationship, and if so, how?

The possible contributions of this study are as follows. At the theoretical level, this study introduces financial flexibility theory into research on the sustainable development of energy enterprises. It also enriches the application of contingency theory in the field of financial strategy. At the methodological level, this study moves beyond single financial indicators and single ESG ratings. It builds a comprehensive index system that includes four dimensions: finance, environment, society, and governance. It uses the objective entropy weight method to measure sustainable development performance. This provides an independent measurement framework. In addition, this study uses a nonlinear regression model and a panel fixed-effects model. The results reveal an inverted U-shaped relationship between financial flexibility and sustainable development performance. They also verify the moderating effect of environmental uncertainty. At the practical level, the findings provide useful guidance for energy enterprises. They show how firms can optimize the allocation of financial flexibility in a complex and uncertain environment. This can help firms balance short-term survival pressure with long-term sustainable development goals.

2. Theoretical Analysis and Research Hypotheses

2.1. Financial Flexibility and Sustainable Development Performance

Financial flexibility mainly arises from cash holdings and unused debt capacity. According to resource constraint theory, energy firms are capital-intensive. Green projects, such as emission reduction initiatives and corporate social responsibility programs, require substantial investment and often have long payback periods [19]. When energy firms face external shocks, those with insufficient financial flexibility may be unable to adjust their capital structure quickly or manage risks effectively. They may therefore delay ongoing projects and reduce expenditure on sustainable development. These resource constraints can weaken their sustainable development performance. A moderate level of financial flexibility can help energy firms ease financing constraints and minimize losses during crises. It can also ensure the steady implementation of sustainable development projects and strengthen corporate resilience. During periods of economic fluctuation, declining interest rates reduce the cost of holding cash. Firms may therefore rely more on cash reserves than on external financing [20]. Moreover, energy firms with moderate financial flexibility have greater freedom in choosing the timing of their investments. When other firms face survival pressure, these firms can maintain their investment capacity by optimizing resource allocation and adjusting strategic decisions. In this way, they can rebuild their competitive advantages and even strengthen their market influence. This supports their long-term sustainable development [21]. Therefore, financial flexibility serves as a key resource buffer for energy firms under environmental uncertainty. It improves their ability to allocate resources dynamically and adjust operational strategies [22]. These capabilities ultimately enhance sustainable development performance.

However, financial flexibility also has costs. Agency theory suggests that excessive cash reserves may give managers too much discretion. This may lead to symbolic and repetitive sustainable investments, which deviate from long-term sustainable development goals [23]. When the costs exceed the benefits, sustainable development performance

will decline. At the same time, an excessively low debt level may cause firms to lose the tax shield benefits and external governance effects of debt [24]. Therefore, financial flexibility can improve sustainable development performance only when it remains within a reasonable range. In this case, it serves as a strategic buffer rather than financial redundancy. From the perspective of dynamic trade-off theory, energy firms face changes caused by oil price fluctuations and dual-carbon policies. These changes continuously affect the adjustment costs of capital structure. Firms need to use the tax shield benefits of debt and dynamically adjust their debt levels. They should also maintain an appropriate amount of unused debt capacity [25]. At the same time, they should avoid excessive debt, because it may crowd out investment in sustainability. In this way, firms can optimize the match between capital structure and sustainable development performance under flexible reserves. At low levels, increasing financial flexibility can ease resource constraints and support sustainable investment. At moderate levels, dynamic trade-offs allow financial flexibility to create the highest value. At high levels, agency costs and resource redundancy may offset its benefits. Therefore, the effect of financial flexibility on sustainable development performance is not linear. It is expected to have an inverted U-shaped effect.

Based on the above analysis, this paper proposes:

H1. *Financial flexibility has an inverted U-shaped impact on the sustainable development performance of energy enterprises.*

2.2. The Moderating Effect of Environmental Uncertainty

Environmental uncertainty reflects unpredictability and instability in a firm's internal and external environment [26]. For energy firms, environmental uncertainty mainly includes energy price fluctuations, changes in environmental regulation, technological substitution, changes in carbon policies, and changes in demand [27]. Contingency theory suggests that no financial strategy is effective for the sustainable development of energy firms in all situations. Its actual effect depends on its dynamic fit with the external environment [16]. To address these challenges, financial flexibility has become a key resource buffer. It helps firms respond to internal and external changes and achieve sustainable development [28]. Under high environmental uncertainty, energy firms face stronger financing frictions and higher operational risks. Due to precautionary motives, they may hold more cash to reduce the risk of cash flow disruption. This can support the operation of sustainable projects [29]. When policy or market opportunities emerge, financial flexibility enables firms to respond quickly. It also helps firms expand into new areas [30]. Therefore, environmental uncertainty increases the value of moderate financial flexibility. However, it may also amplify the costs of excessive financial flexibility. When the external environment is unstable, managers may hold too much cash for precautionary reasons. They may also delay sustainable development decisions and face greater difficulty in making investment choices. Therefore, environmental uncertainty may make the inverted U-shaped curve steeper. This means that environmental uncertainty may strengthen both the intensity and the shape of the effect of financial flexibility on sustainable development performance. Based on this, this paper proposes:

H2. *Environmental uncertainty can positively moderate the inverted U-shaped relationship between financial flexibility and the sustainable development performance of energy enterprises.*

3. Data and Sample Construction

3.1. Data Source

This paper selects the listed companies in the energy sector of Shanghai and Shenzhen A-shares from 2019 to 2023 as the initial sample. The industry definition is based

on the “Statistical Classification and Codes for Listed Companies” issued by the China Securities Regulatory Commission (2021). The sample is processed as follows: ST and *ST companies are excluded; observations with missing key variables are removed; all continuous variables are trimmed by 5% at the upper and lower ends to control extreme values. Finally, 171 energy enterprises and 855 sample observations are obtained. Financial data comes from the CSMAR and Wind databases, and ESG-related data is compiled from the company’s annual reports and social responsibility reports.

3.2. Variable Definition

1. Dependent variable: Sustainable development performance (sus). Since ESG ratings may not fully capture the features of Chinese energy firms, this study develops a comprehensive index system tailored to their specific context. The system covers four dimensions: finance, environment, society, and governance, as shown in Table 1. The entropy method is used to determine indicator weights and calculate the overall score. This method is suitable because sustainable development performance is multidimensional and can reduce subjective bias in weight assignment.

Table 1. Sustainable Development Performance Evaluation Indicator System.

First-Level Indicator	Second-Level Indicator	Third-Level Indicator	Fourth-Level Indicator	Indicator Explanation
Sustainable Development Performance	Financial Performance	Profitability	Operating Profit Margin	$\frac{\text{Operating Profit}}{\text{Operating Income}} \times 100\%$
			Return on Total Assets	$\frac{\text{EBIT}}{\text{Average Total Assets}} \times 100\%$
		Operating Capacity	Inventory Turnover Ratio	$\frac{\text{Operating Cost}}{\text{Average Inventory Balance}}$
			Accounts Receivable Turnover Ratio	$\frac{\text{Credit Sales}}{\text{Average Accounts Receivable Balance}} \times 100\%$
		Solvency	Current Ratio	$\frac{\text{Current Assets}}{\text{Current Liabilities}}$
			Asset-Liability Ratio	$\frac{\text{Total Liabilities}}{\text{Total Assets}} \times 100\%$
		Development Capacity	Operating Income Growth Rate	$\frac{\text{Current Year Operating Income} - \text{Last Year Operating Income}}{\text{Last Year Operating Income}} \times 100\%$
			Total Assets Growth Rate	$\frac{\text{Current Year Total Assets} - \text{Last Year Total Assets}}{\text{Last Year Total Assets}} \times 100\%$
	Environmental Performance	Resource Utilization Efficiency	Per Capita Water Resource Consumption	$\frac{\ln(\text{Water resource consumption (tons)})}{\text{Number of employees}}$
			Per Capita Electricity Resource Consumption	$\frac{\ln(\text{Electricity consumption (kWh)})}{\text{Number of employees}}$
		Pollution Control Status	Environmental Protection Tax	$\ln(\text{Environmental protection tax})$
			Per Capita CO ₂ Emission Reduction	$\frac{\ln(\text{CO}_2 \text{ reduction})}{\text{Number of employees}}$
		Environmental Management Practices	ISO Environmental Management Certification	1 = Certified, 0 = Not certified
			Per Capita Environmental Protection Investment	$\frac{\text{Environmental protection investment (ten thousand yuan)}}{\text{Number of employees}}$

Table 1. Cont.

First-Level Indicator	Second-Level Indicator	Third-Level Indicator	Fourth-Level Indicator	Indicator Explanation
Sustainable Development Performance	Social Performance	Employee Rights and Interests	Employee Income Level	Annual employee income/Number of employees
			Proportion of Female Management	Number of female managers/Total number of managers
		Responsibility Response	Whether to Disclose Social Responsibility Report	1 = Disclosed, 0 = Not disclosed
			Number of Violations	Unit: Cases
		Social Contribution	Number of Social Welfare Activities	Number of disclosed social welfare and community engagement activities; used as a supplementary proxy for social responsibility participation. Unit: cases.
			Social Donation Amount	ln (Social donation amount)
	Governance Performance	Governance Structure	Number of Shareholder Meetings	Frequency of formal shareholder governance activities; used as a proxy for governance participation. Unit: times.
			Ownership Balance Degree	(Sum of shareholding ratios excluding the largest shareholder)/Shareholding ratio of the largest shareholder
		Supply Chain Level	Supplier Concentration	(Procurement amount from top 5 suppliers/Total procurement amount) $\times$ 100%
			Customer Concentration	(Sales to top 5 customers/Total sales) $\times$ 100%
		R&D and Innovation Level	R&D Investment-to-Operating Income Ratio	(R&D investment/Operating income) $\times$ 100%
			R&D Personnel Proportion	(Number of R&D personnel/Total number of employees) $\times$ 100%

2. Explanatory variable: Financial flexibility (ff). Following the method proposed by Zeng Aimin et al. [3], ff = cash flexibility + debt flexibility. Here, cash flexibility = enterprise cash ratio—industry cash ratio; debt flexibility = max (industry average debt ratio—enterprise debt ratio, 0). Additionally, the square term of ff (ff²) is also constructed.

3. Regulating variable: Environmental uncertainty (eu). Following the approach of Shen Huihui [31], this is calculated based on the standard deviation of the regression residuals of the company's sales revenue over the past five years, and then adjusted according to the industry. This indicator was adopted because fluctuations in market demand, customer orders, industry cycles, energy prices, and external shocks are ultimately reflected in firms' sales performance.

4. Control variables. These include enterprise size (size), equity concentration (top10), dual positions (dual), Tobin's q value (Tobinq), earnings before interest and taxes (ebit), whether the company is disclosing in accordance with GRI standards (GRI), and return on invested capital (roic). At the same time, control is provided for fixed effects of year (Year), industry (Industry), and individual (Id).

All Variable Definition are shown in Table 2.

Table 2. Variable Definitions.

Variable Type	Variable Name	Symbol	Variable Definition
Dependent Variable	Sustainable Development Performance	sus	Constructed using the indicator system
Independent Variable	Financial Flexibility	ff	Financial Flexibility = Cash Flexibility + Debt Flexibility; Cash Flexibility = Corporate cash holding ratio – Industry average cash holding ratio; Debt Flexibility = max(0, Industry average debt ratio – Corporate debt ratio)
	Financial Flexibility Squared	ff2	The square of ff
Moderating Variable	Environmental Uncertainty	eu	(Standard deviation of abnormal sales revenue over five years/Average sales revenue over five years)/Industry median
Control Variables	Firm Size	size	ln(total corporate assets)
	Ownership Concentration	top10	Shareholding ratio of the top ten shareholders
	CEO-Chairman Duality	dual	1 if the CEO and Chairman are the same person; 0 otherwise
	Tobin's q	Tobinq	Market value of the firm/Replacement cost of assets
	Earnings Before Interest and Taxes	ebit	Net profit + Interest expense + Income tax expense, in 100 million yuan
	Environmental Information Disclosure	rev	Whether the firm discloses environmental information in accordance with the GRI Sustainability Reporting Standards; 1 = Yes, 0 = No
	Return on Invested Capital	roic	Net Operating Profit After Tax (NOPAT)/Invested Capital

3.3. Model Specification

To test the hypotheses proposed in this paper, the following regression model is constructed:

$$\text{sus}_{i,t} = \alpha_0 + \alpha_1 \text{ff}_{i,t} + \alpha_2 \text{ff}_{i,t}^2 + \alpha_3 \text{size}_{i,t} + \alpha_4 \text{top10}_{i,t} + \alpha_5 \text{dual}_{i,t} + \alpha_6 \text{tobinq}_{i,t} + \alpha_7 \text{ebit}_{i,t} + \alpha_8 \text{rev}_{i,t} + \alpha_9 \text{roic}_{i,t} + \sum \text{id}_{i,t} + \sum \text{year}_{i,t} + \sum \text{industry}_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$\text{sus}_{i,t} = \alpha_0 + \alpha_1 \text{ff}_{i,t} + \alpha_2 \text{ff}_{i,t}^2 + \alpha_3 \text{eu}_{i,t} + \alpha_4 \text{ff_eu}_{i,t} + \alpha_5 \text{ff}_{i,t}^2 \text{eu}_{i,t} + \alpha_6 \text{size}_{i,t} + \alpha_7 \text{top10}_{i,t} + \alpha_8 \text{dual}_{i,t} + \alpha_9 \text{tobinq}_{i,t} + \alpha_{10} \text{ebit}_{i,t} + \alpha_{11} \text{rev}_{i,t} + \alpha_{12} \text{roic}_{i,t} + \sum \text{id}_{i,t} + \sum \text{year}_{i,t} + \sum \text{industry}_{i,t} + \varepsilon_{i,t} \quad (2)$$

4. Empirical Tests and Results

4.1. Descriptive Statistics

The descriptive statistics of the relevant variables are shown in Table 3. The results indicate that there are certain differences in the sustainable development performance among different enterprises, but they all generally have certain sustainable development performance. The maximum value is 0.67, the minimum value is 0.1, and the average value is 0.36. In the explanatory variable of financial flexibility, the minimum value is −0.17, the maximum value is 0.68, and the average value is 0.08. It can be seen that the level of financial flexibility varies greatly, and the average value is generally greater than 0, indicating that most of the research variables have adopted appropriate financial flexibility reserves, but there are negative values, indicating that some energy enterprises

have insufficient financial flexibility reserves. The minimum value of the moderating variable of environmental uncertainty is 0.10, the maximum value is 6.59, and the average value is 1.26, indicating that the environmental uncertainty faced by enterprises is quite volatile.

Table 3. Descriptive Statistics.

Variable	N	Mean	SD	Min	Max
sus	855	0.360	0.100	0.100	0.670
ff	855	0.080	0.150	−0.170	0.680
ff2	855	0.030	0.060	0.000	0.470
eu	855	1.261	0.930	0.105	6.594
size	855	10.240	0.710	8.150	12.440
top10	855	0.640	0.170	0.130	0.970
dual	855	0.130	0.340	0.000	1.000
tobinq	855	1.390	1.280	0.770	15.490
ebit	855	48.180	180.600	−57.000	2600
rev	855	1.690	0.460	1.000	2.000
roic	855	0.050	0.080	−0.870	0.400

This study uses the variance inflation factor (VIF) to test for multicollinearity among the variables. As shown in Table 4, the VIF values of all variables are far below the critical value of 10. The mean VIF is 2.21, and the mean 1/VIF is 0.597. Together with the Pearson correlation coefficients, these results indicate that there is no serious multicollinearity problem. Therefore, the empirical analysis of the hypotheses can be further conducted.

Table 4. Multicollinearity Test.

Variable	VIF	1/VIF
ff	4.48	0.223
ff2	4.21	0.237
size	3.18	0.315
top10	1.63	0.613
tobinq	1.47	0.682
ebit	1.45	0.691
rev	1.36	0.734
roic	1.08	0.924
dual	1.05	0.952
Mean VIF	2.21	0.597

4.2. Baseline Regression

1. Financial flexibility and enterprise sustainable development performance. In Table 5, column (1) shows the regression results of financial flexibility alone without including the square term of financial flexibility. It is significant at the 10% level and the regression coefficient is 0.068. Column (2) shows the regression results of financial flexibility on sustainable development performance without including control variables. It can be seen that the regression coefficient of financial flexibility is 0.141, which is significant

at the 5% level. The significance level increases, and the regression coefficient of the square term of financial flexibility is -0.211 , also significant at the 5% level. This indicates that without including control variables, the inverted U-shaped influence relationship of financial flexibility on enterprise sustainable development performance is obvious. Column (3) shows the regression result with the square term of financial flexibility included. The square term of financial flexibility is significantly negative at the 5% significance level, with a coefficient of -0.145 , while the linear term of financial flexibility is significantly positive at the 5% significance level, with a coefficient of 0.122 . It can be seen that the relationship between sustainable development performance and financial flexibility is a nonlinear relationship. Specifically, sustainable development performance first increases and then decreases as financial flexibility rises. This pattern is consistent with an inverted U-shaped relationship and provides preliminary support for H1. Economically, this result suggests that moderate financial flexibility helps energy enterprises maintain financial buffers and support sustainability-related investments, whereas excessive financial flexibility may lead to resource slack, agency costs, and inefficient allocation, thereby weakening sustainable development performance.

Table 5. The Results of Baseline Regression.

	(1)	(2)	(2)
Variable	Sus	Sus	Sus
ff	0.068 *	0.141 **	0.122 **
	(0.030)	(0.048)	(0.040)
ff2		-0.211 **	-0.145 **
		(0.065)	(0.052)
size	0.045 ***		0.045 ***
	(0.010)		(0.011)
top10	0.077 **		0.072 **
	(0.024)		(0.023)
dual	0.006		0.006
	(0.005)		(0.004)
tobinq	0.002		0.002
	(0.004)		(0.004)
ebit	0.000 ***		0.000 ***
	(0.000)		(0.000)
rev	-0.030 ***		-0.029 ***
	(0.005)		(0.005)
roic	0.066 **		0.066 **
	(0.024)		(0.026)
_cons	-0.142	0.358 ***	-0.134
	(0.090)	(0.002)	(0.109)
N	855	855	855
r2	0.940	0.929	0.940
Year	Yes	Yes	Yes

Table 5. *Cont.*

	(1)	(2)	(2)
Variable	Sus	Sus	Sus
Id	Yes	Yes	Yes
Industry	Yes	Yes	Yes

Note: Robust standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

To further confirm its inverted U-shaped relationship, the Utest test was introduced. As shown in Table 6, the minimum value of the test interval is -0.17 , the maximum value is 0.68 , the left-end slope is 0.156 and it is significant at the 1% level, indicating a positive correlation at the left end, which is consistent with the fact that financial flexibility has a significant promoting effect on sustainable development performance. The right-end slope is -0.108 and it is significant at the 5% level, indicating a negative correlation at the right end. Financial flexibility has a significant inhibitory effect on sustainable development performance. In summary, the research results show that there is a significant inverted U-shaped relationship between the variables, that is, when the financial flexibility variable is small, its increase will improve the sustainable development performance of the enterprise. When the independent variable exceeds the extreme point, further increasing financial flexibility will lead to a decrease in the sustainable development performance of the enterprise. This relationship is statistically significant.

Table 6. The Test of Inverted U-Shape.

	Lower Bound	Upper Bound
Interval	-0.170	0.680
Slope	0.157	-0.108
t-value	3.241	-2.506
$p > t$	0.009	0.023

To further explain the inverted U-shaped relationship between the variables more intuitively, a graph of the inverted U-shaped relationship between financial flexibility and sustainable development performance is made, as shown in Figure 1. The x-axis represents the independent variable—financial flexibility, and the y-axis represents the dependent variable—sustainable development performance. It can be seen that the minimum value of the independent variable is -0.17 , and the maximum value is 0.68 . The extreme point is reached when the financial flexibility is 0.42 . After reaching the extreme point, there is a turning point in financial flexibility, and as financial flexibility increases, sustainable development performance decreases. This image further verifies the validity of the assumptions made in this paper.

2. Analysis of the moderating effect of environmental uncertainty. We introduce environmental uncertainty as a moderating variable to analyze how it affects the inverted U-shaped link between financial flexibility and sustainable development performance, as shown in Table 7. In column (1), the regression results after adding the moderating variable environmental uncertainty, the product term of environmental uncertainty and financial flexibility (ff_eu), and the squared product term of environmental uncertainty and financial flexibility ($ff2_eu$) are presented. The results show that the product term of environmental uncertainty and financial flexibility is negatively correlated at a 10% significance level, with a correlation coefficient of -0.043 , and the squared product term of financial flexibility is positively correlated at a 5% significance level, with a correlation coefficient of 0.104 .

These results suggest that environmental uncertainty moderates the relationship between financial flexibility and sustainable development performance. Compared with the original regression equation in column (2), the R^2 of column (1) is higher than that of the original equation, which also confirms that environmental uncertainty optimizes the original model, making the estimation results more reliable. Further analysis shows that, as can be seen from the original regression results in columns (1) and (2), after the introduction of the environmental uncertainty variable, the steepness of the inverted U-shaped curve is related to the quadratic coefficient. The quadratic coefficient of column (1) is -0.298 , and that of column (2) is -0.145 . It can be seen that after introducing the environmental uncertainty variable, the absolute value of the quadratic coefficient increases, that is, the curve becomes steeper. That is, with the increase in environmental uncertainty, the impact of financial flexibility on enterprise sustainable development performance is amplified.

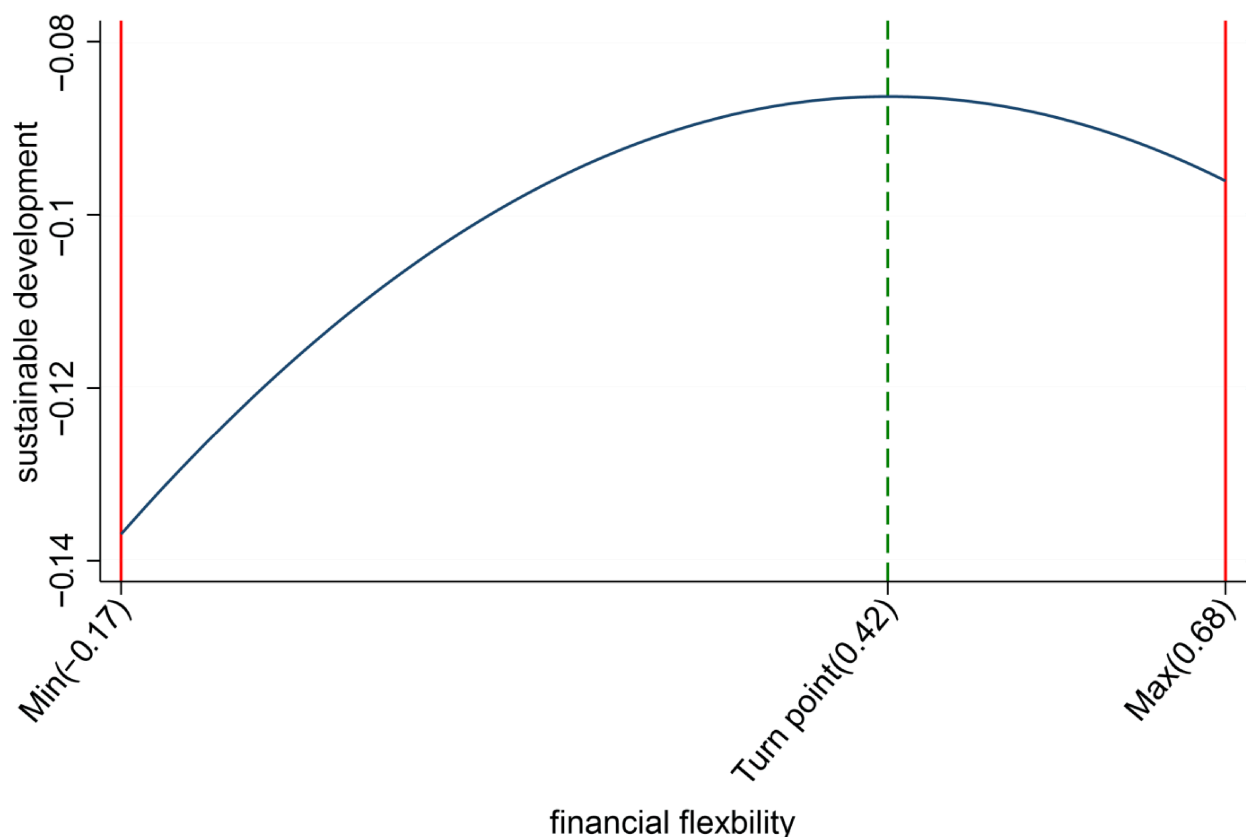


Figure 1. The Inverted U-Shaped Relationship.

To gain a more intuitive understanding of the moderating effect brought about by environmental uncertainty, the moderating effect diagram in Figure 2 is used to represent the impact of environmental uncertainty. As shown in Figure 2, after the emergence of environmental uncertainty, the inverted U-shaped curve becomes steeper, further confirming the moderating effect of environmental uncertainty on the relationship between financial flexibility and sustainable development performance. This change in slope demonstrates that environmental uncertainty positively moderates the inverted U-shaped relationship. Specifically, under conditions of high environmental uncertainty, moderately increasing financial flexibility can cope with the challenges brought about by changes in the external environment. Moreover, compared to low environmental uncertainty, the optimal value of financial flexibility shifts to the left from 0.42 to 0.31, reducing by 0.11 units. This indicates that in this condition, a lower level of financial flexibility can achieve the desired state of sustainable development performance.

Table 7. Analysis of the adjustment effect of environmental uncertainty.

	(1)	(2)
Variable	Sus	Sus
ff	0.181 ** (3.135)	0.122 ** (3.086)
ff2	−0.298 *** (−4.857)	−0.145 ** (−2.790)
eu	−0.041 (−0.851)	
ff2_eu	0.104 ** (2.489)	
ff_eu	−0.043 * (−1.980)	
size	0.044 ** (3.241)	0.045 *** (3.895)
top10	0.073 *** (4.149)	0.072 ** (3.077)
dual	0.007 (1.564)	0.006 (1.412)
tobinq	0.002 (0.494)	0.002 (0.484)
ebit	0.000 *** (4.956)	0.000 *** (5.605)
rev	−0.029 *** (−5.304)	−0.029 *** (−5.465)
roic	0.068 ** (2.771)	0.066 ** (2.530)
_cons	−0.049 (−0.329)	−0.105 (−0.957)
N	855	855
r2	0.941	0.940
Year	Yes	Yes
Id	Yes	Yes
Industry	Yes	Yes

Note: Robust standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

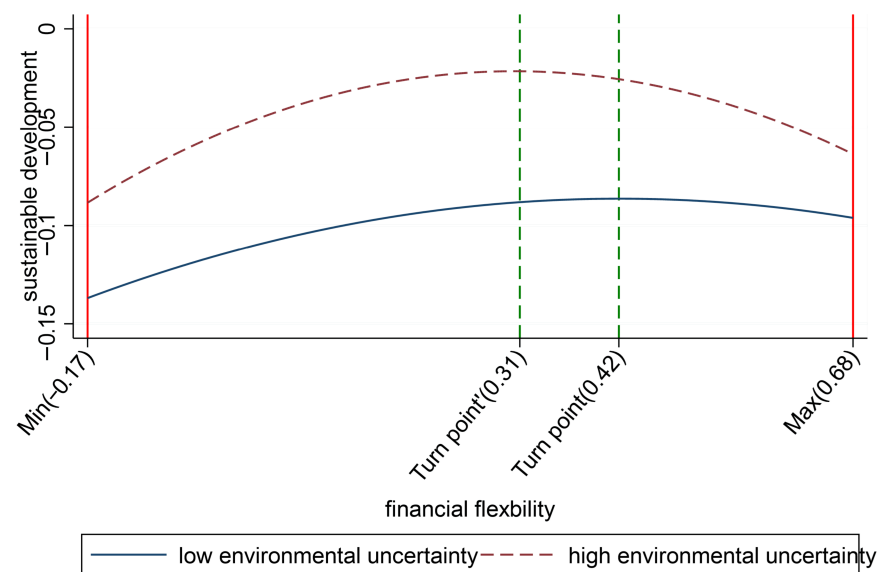


Figure 2. Environmental Uncertainty Adjustment Effect Diagram.

4.3. Robustness Test

1. Incorporate the cube of the explanatory variable. The robustness test of the nonlinear relationship usually involves including the cube of the core explanatory variable in the regression, mainly to verify the stability of the nonlinear relationship and prevent model specification errors. If the cubic term is significant, it indicates that there are more complex nonlinear relationships in the data, such as an “S-shaped” curve. Using only the quadratic term may not be able to determine the authenticity of the relationship. As shown in Table 8 column (1) of, if the cube of financial flexibility is not significant, it indicates that the quadratic model has adequately described the inverted U-shaped structure, thereby enhancing the reliability of the results.

Table 8. Robustness Tests.

	(1)	(2)	(3)
Variable	Sus	Sus1	Sus
ff	0.137 *** (0.034)	0.134 *** (0.026)	0.121 ** (0.035)
ff2	−0.305 (0.163)	−0.132 ** (0.039)	−0.167 *** (0.041)
ff3	0.230 (0.258)		
size	0.043 *** (0.010)	0.032 * (0.014)	0.037 * (0.018)
top10	0.070 ** (0.025)	0.056 (0.035)	0.073 ** (0.024)
dual	0.006 (0.004)	0.005 (0.004)	0.006 (0.004)
tobinq	0.002 (0.004)	0.001 (0.003)	0.000 (0.003)

Table 8. *Cont.*

	(1)	(2)	(3)
Variable	Sus	Sus1	Sus
ebit	0.000 *** (0.000)	0.000 *** (0.000)	0.000 ** (0.000)
rev	0.029 *** (0.005)	0.031 *** (0.005)	0.029 *** (0.005)
roic	0.066 ** (0.025)	0.064 ** (0.020)	0.113 *** (0.028)
_cons	−0.147 (0.092)	−0.108 (0.128)	−0.087 (0.172)
N	855	855	855
r ²	0.941	0.944	0.940
Year	Yes	Yes	Yes
Id	Yes	Yes	Yes
Industry	Yes	Yes	Yes

Note: Robust standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

2. Replace the dependent variable. Under the condition that other variables remain unchanged, based on the triple bottom line theory, which encompasses economic, social, and environmental aspects, the indicators constructed in the previous text are utilized to calculate the sustainable development performance score. The original dependent variable is replaced. According to the results shown in Table 8, the sustainable development performance calculated through the triple bottom line theory (sus1) indicates that the replaced dependent variable is significantly positive in relation to the first term of financial flexibility at the 1% significance level, and the square of financial flexibility is significantly negative at the 5% significance level. The empirical results are consistent with and significant in direction to the regression results presented earlier, indicating that the model is robust.

3. Sample trimming by 1%. To eliminate the excessive influence of extreme values in the regression, the data of all variables were trimmed by 1% (i.e., the extreme values at both ends of the data were replaced with the adjacent percentiles), and then the regression was conducted. According to the regression in Table 8 column (3), financial flexibility remained significantly positive at the 5% level, the square of financial flexibility remained significantly negative at the 1% level, It can be concluded that the results are not sensitive to extreme values, indicating that the model is robust.

4. Threshold Effect. When conducting robustness tests for nonlinear variable relationships, in addition to the traditional robustness methods such as replacing the dependent variable, introducing the cube of the core explanatory variable, and tailing the sample by 1%, one can also refer to Zhu Yufei's [32] method to use the threshold effect to conduct robustness tests for the inverted U-shaped phenomenon. The threshold effect refers to a situation in which the relationship between two economic variables changes once a key variable reaches a certain critical value. By using the core explanatory variable as the threshold variable, based on the results of the threshold test in the Table 9, it can be seen that the results are significant at the 10% level of a single threshold, and the double thresholds are not significant, indicating that the financial flexibility of enterprises has a single threshold effect. The threshold value is 0.12. The threshold regression reveals a posi-

tive correlation below the threshold value and a negative correlation above the threshold value. The threshold regression provides additional evidence that financial flexibility has a nonlinear effect on sustainable development performance, which is broadly consistent with the inverted U-shaped relationship identified in the baseline regression. To visualize the impact of the single threshold effect, an LR curve graph was made, as shown in Figure 3. It can be seen that at the threshold value of 0.12, as indicated by the dotted line, there is a significant change in the value, thereby verifying the existence of a single threshold between the variables, and the nonlinear relationship between financial flexibility and sustainable development performance, demonstrating the robustness of the research results of this paper.

Table 9. Threshold Effect Test Results.

Variable	Threshold Type	F-Statistic	p-Value	Threshold Value	Lower Bound of Confidence Interval	Upper Bound of Confidence Interval
ff	Single Threshold	9.520	0.070	0.120	0.025	0.130
ff	Double Threshold	3.240	0.580	0.260	0.250	0.270

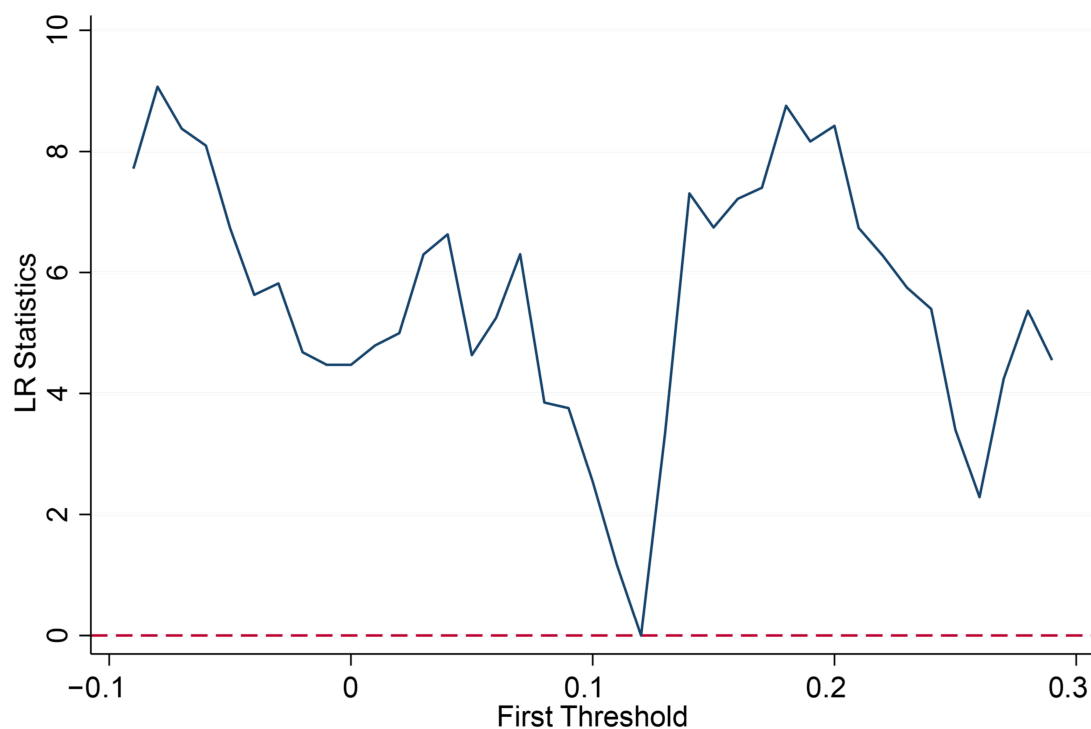


Figure 3. Single Threshold Effect Plot.

4.4. Heterogeneity Test

1. First, this study classifies energy firms by ownership type. Since ownership type may affect the level of financial flexibility, the sample is divided into state-owned enterprises and non-state-owned enterprises for heterogeneity analysis. As shown in columns (1) and (2) of Table 10, the regression result is significant for state-owned enterprises, but not significant for non-state-owned enterprises. This suggests that state-owned energy firms pay more attention to sustainable development performance. State-owned enterprises usually have a long-term strategic orientation. With government support, they also have lower financing costs [33]. This helps them steadily transform financial flexibility into sustainability-related investment [34]. Therefore, the inverted U-shaped relationship is more significant among state-owned energy firms.

Table 10. Heterogeneity Test.

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	SOEs	Non-SOEs	Eastern Region	Central and Western Regions	New Energy Enterprises	Traditional Energy Enterprises
ff	0.139 *** (0.033)	0.083 (0.096)	0.127 (0.088)	0.104 ** (0.039)	0.106 * (0.040)	0.121 * (0.059)
ff2	−0.152 *** (0.027)	−0.057 (0.139)	−0.108 (0.172)	−0.156 *** (0.039)	−0.007 (0.065)	−0.170 * (0.073)
size	0.046 ** (0.017)	−0.015 (0.033)	0.090 (0.049)	0.004 (0.028)	0.057 ** (0.015)	0.042 * (0.020)
top10	0.049 * (0.024)	0.025 (0.043)	0.088 (0.046)	0.088 * (0.037)	−0.005 (0.019)	0.101 ** (0.026)
dual	0.010 ** (0.004)	0.006 (0.012)	0.002 (0.010)	0.009 (0.009)	0.017 ** (0.003)	−0.001 (0.006)
tobinq	0.005 (0.005)	−0.003 (0.007)	0.006 ** (0.002)	−0.001 (0.008)	−0.010 (0.010)	0.005 (0.005)
ebit	0.000 *** (0.000)	0.000 ** (0.000)	0.000 *** (0.000)	0.000 ** (0.000)	0.000 ** (0.000)	0.000 ** (0.000)
rev	0.022 *** (0.005)	0.057 ** (0.017)	0.024 *** (0.005)	0.033 ** (0.010)	−0.026 ** (0.005)	−0.032 ** (0.007)
roic	0.094 *** (0.013)	0.035 (0.042)	0.045 *** (0.010)	0.064 (0.050)	0.135 * (0.057)	0.054 * (0.026)
_cons	−0.169 (0.171)	0.457 (0.326)	−0.631 (0.483)	0.232 (0.259)	−0.177 (0.155)	−0.092 (0.224)

Note: Robust standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

2. Classified by the geographical distribution of energy enterprises. There are differences in the economic development levels among various regions, so this paper divides the enterprises into the eastern and central-western regions for heterogeneity testing. As shown in columns (3) and (4) of Table 10, the regression in the central-western region is significant, while that in the eastern region is not. From regional characteristics, central-western areas gather more traditional energy enterprises, which feature large capital spending in environmental governance and transformation activities. In addition, central-western energy enterprises have weaker external financing capacity than eastern enterprises, and rely more on internal capital reserves. Meanwhile, fiscal transfer payments and government subsidy resources in central-western areas also correlate with enterprises' sustainable investment behaviors [35].

3. Classified by the energy nature of the enterprises. There are differences in the industrial categories of traditional energy enterprises and new energy enterprises. The samples are classified into two groups for testing Eastmoney Network's new energy strategy section companies as new energy enterprises, and other companies as traditional energy enterprises. Column (5) and Column (6) of Table 10 show that new energy enterprises are not significant, while traditional energy enterprises are significant. In terms of enterprise operational characteristics, most traditional energy enterprises have entered a mature development cycle, with adjustable capital arrangement and business layout conditions. These enterprises are also facing ongoing industrial transformation requirements, which are linked to their sustainable development performance changes [36].

5. Conclusions and Recommendations

5.1. Main Conclusions

Firstly, this paper identifies an inverted U-shaped nonlinear relationship between financial flexibility and the sustainable development performance of energy enterprises. This indicates that when the level of financial flexibility is moderate, it can provide sufficient financial buffers and financing potential to effectively support energy enterprises in making forward-looking investments in key areas of sustainable development, thereby enhancing their overall performance. However, beyond the critical point, due to resource constraints and agency problems, it will instead have a restraining effect.

Secondly, environmental uncertainty moderates the aforementioned inverted U-shaped relationship. This means that when the external environment is complex and changeable, the capabilities of moderate financial flexibility are significantly amplified. Enterprises can utilize this flexible resource to respond more quickly and flexibly to the challenges and opportunities brought about by environmental uncertainty. Conversely, in a stable environment, the strategic value of financial flexibility is relatively limited.

The impact of financial flexibility on sustainable development performance shows significant heterogeneity. Grouped tests indicate that state-owned energy enterprises with different ownership characteristics undertake and accept more explicit policies and social responsibilities, and financial flexibility can more effectively serve the macro requirements of sustainable development. In terms of regional distribution, energy enterprises in the central and western regions face strong financing constraints and transformation pressures, and have a higher reliance on internal financial flexibility. In terms of industry type, traditional energy enterprises are in the critical stage of low-carbon transformation and require huge capital investment for business upgrading, and financial flexibility plays a key role.

5.2. Countermeasures and Suggestions

Based on the above research conclusions, this article puts forward the following targeted suggestions from the perspectives of enterprises, the government, and investors, respectively.

1. Enterprise level. Firstly, based on the enterprise's life cycle stage, industry characteristics, and macro-environment expectations, set a reasonable range for financial flexibility that is suitable for strategic goals, and establish a dynamic early warning and adjustment mechanism based on deviation. Secondly, promote the deep integration of financial resources and ESG strategies, systematically incorporate ESG factors into capital budgets, establish green funds or sustainable development reserves, and prioritize investment in key areas of sustainable development, achieving a coordinated improvement of financial performance and social environmental value. Finally, improve corporate governance to mitigate agency risks, perfect the internal control supervision system, strengthen substantive supervision by the board of directors and the board of supervisors, carefully assess the environmental and social impacts of major investment projects, and prevent resource misallocation.

2. Government level. Firstly, implement differentiated incentive and restraint mechanisms. Provide tax incentives to enterprises that invest in the research and development of clean energy and energy efficiency improvements. For enterprises with insufficient investment in environmental protection and safety, strengthen supervision and warning. Secondly, accelerate the establishment of a comparable ESG information disclosure system for the energy industry, and mandatorily disclose financial flexibility strategies to enhance market supervision effectiveness. Finally, provide more support for transformation finance

in the central and western regions and traditional energy concentration areas, reduce financing costs, and enhance the financial resilience of enterprises.

3. Investor level. Firstly, innovate the valuation model by systematically integrating financial flexibility quality and ESG performance into traditional financial analysis. Be vigilant of the agency risks implied by high cash reserves but lack of sustainable investment planning. Secondly, incorporate environmental uncertainty into the decision-making framework and prioritize identifying investments that can rely on financial flexibility to achieve sustainable development performance and have strong adaptability. Lastly, uphold long-termism. Investors should actively participate in shareholder actions, urging enterprises to coordinate financial flexibility management with long-term sustainable development goals, avoiding short-term trading behaviors and jointly creating shared value in economic, social, and environmental dimensions.

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