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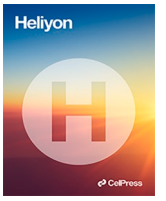

Review article

The nonlinear impact of financial flexibility on corporate sustainability: Empirical evidence from the Chinese manufacturing industry

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ABSTRACT

In the face of challenges ushered in by globalization and technological advancements, financial flexibility has emerged as a pivotal strategy for attaining sustainable development in China's manufacturing sector. Financial flexibility allows firms to manage internal cash flows, alleviate external financing constraints, and augment their capability to absorb risks. Using the framework of Financial Flexibility Theory and Institutional Theory, this study examines data from A-share listed manufacturing firms on the Shanghai and Shenzhen Stock Exchanges from 2011 to 2021. The research aims to investigate the nexus between financial flexibility and sustainable performance, while also probing the moderating roles of environmental uncertainty and governmental grants. The key findings of the study unveil an inverted U-shaped relationship between financial flexibility and sustainable performance. Moreover, environmental uncertainty exerts a significant negative influence on sustainable performance. When both environmental uncertainty and governmental grants are substantial, the inverted U-shaped correlation between financial flexibility and sustainable performance intensifies. The innovation of this study lies in revealing the optimal zone of financial flexibility for enterprises under the influence of environmental uncertainty and government grants. Amidst an increasingly intricate macro-environment, this research furnishes pragmatic insights for optimizing sustainable performance in manufacturing enterprises and offers a series of empirically grounded suggestions for enterprise managers, government departments, and investors, guiding them to enhance sustainable performance through judicious calibration of financial flexibility levels.

1. Introduction

As the global economy and technology rapidly evolve, and environmental crises intensify, sustainable development has become one of the most urgent challenges facing contemporary society. This is particularly pronounced in the manufacturing sector, where there is significant consumption of resources and potential environmental impact. Against this backdrop, China's 'dual carbon' goals not only signify the nation's high-level commitment to ecological and environmental protection but also set higher standards for the transformation and upgrading of the manufacturing industry. Manufacturing companies are required to not only continually improve product quality and adopt green processes but also to flexibly respond to drastic market changes and frequent fluctuations in demand

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[1]. This transition often involves substantial financial pressure and risk for these companies [2]. Hence, in pursuing sustainable development, it is crucial for businesses to have flexible financial resource management to cope with these risks and challenges [3]. In this context, understanding and assessing the role of financial flexibility in the sustainable development of manufacturing companies becomes particularly important.

Financial flexibility plays a crucial role for manufacturing companies in responding to market dynamics and environmental challenges. It emphasizes the flexibility and adaptability of capital management [4], and as a strategy that enhances a company's adaptability and response to market changes, it is regarded as an essential tool for businesses to handle unknown market variations and achieve sustainable development [5]. Financial flexibility significantly promotes sustainable development by enhancing a company's ability to adapt to market changes and by supporting long-term sustainable investments. It not only helps businesses manage economic fluctuations and risks effectively but also provides the necessary funding for environmentally friendly technologies and innovations, thus promoting green transformation while maintaining financial health [6–9]. The importance of financial flexibility is widely recognized in academic circles, but discussions on its specific role and mechanisms in achieving sustainable development in businesses are still relatively limited. Existing studies often overly emphasize the positive role of financial flexibility in helping businesses adapt to market changes and mitigate financial risks, neglecting that an excessive reliance on financial flexibility might lead businesses to overlook the long-term development of their core competencies, thereby negatively impacting their sustainable development. According to financial flexibility theory, when the level of financial flexibility exceeds a certain threshold, it may inhibit the long-term development of the company [4]. This raises an important question about the appropriateness of financial flexibility. Excessive financial flexibility might lead to overly flexible decision-making, lacking in long-term strategic planning and stable development direction, which could negatively affect sustainable development [10]. Therefore, a deeper exploration of the impact of financial flexibility on the sustainable development of manufacturing companies and identifying a theoretical threshold becomes the focus of this study.

With the rapidly changing market and policy environments, environmental uncertainty increasingly plays a critical role in the modern business operating environment [11]. Environmental uncertainty includes factors such as market fluctuations, policy changes, and technological innovations, which profoundly impact a company's operations and strategic decision-making. Its presence elevates the complexity and risk of business operations, altering the need and usage of financial flexibility, and forcing companies to adjust their financial strategies more frequently to adapt to the ever-changing market demands and competitive pressures. In such uncertain environments, financial flexibility becomes crucial for companies to respond to contingencies and seize market opportunities [12,13]. However, this uncertainty may also increase a company's reliance on financial flexibility, impacting long-term strategic planning and resource allocation [12,13]. Therefore, the relationship between financial flexibility and sustainable development in manufacturing companies is likely influenced by environmental uncertainty. Furthermore, government subsidies, as a form of external resources in an institutional environment, have a significant impact on a company's financial decisions and sustainable development strategies. Especially in China's manufacturing industry, where state-owned enterprises have a substantial presence, this might indicate favorable government-business relations. Government financial support can directly enhance a company's financial flexibility, encouraging greater investment in environmental protection and sustainability, such as investing in clean energy, emission reduction technologies, and green innovations [14,15]. This external financial support might alter the way companies utilize financial resources, thereby moderating the impact of financial flexibility on sustainable development strategies to some extent. However, companies might also develop an over-reliance on government subsidies, leading to inertia in financial planning and strategy, overly focusing on projects that meet subsidy criteria, and deviating from their core strategies or neglecting long-term investments in other key areas [14,15]. Thus, the relationship between financial flexibility and sustainable development in manufacturing companies may also be influenced by government grants. Existing research has considered external environmental factors like market competition and technological changes, exploring their impact on the relationship between financial flexibility and corporate sustainable development [16]. However, studies on how environmental uncertainty and government grants modulate this relationship are still relatively scarce. Therefore, exploring the moderating roles of environmental uncertainty and government grants between financial flexibility and sustainable development in manufacturing companies is vital for deepening the understanding of the boundary conditions of financial flexibility and promoting sustainable development in the manufacturing sector.

The marginal contributions of this study are primarily reflected in the following aspects: Firstly, by exploring the nonlinear relationship between financial flexibility and corporate sustainable development performance, this paper not only enriches the research on corporate sustainable development from a micro-perspective but also provides deeper insights into this complex relationship. Secondly, by incorporating environmental uncertainty and government grants into the analysis, this study reveals how these factors modulate the relationship between financial flexibility and sustainable development performance, thereby highlighting the significance of external environmental factors in corporate strategic decision-making. Lastly, this research offers a new perspective in exploring the optimal level of corporate financial flexibility, providing practical guidance for companies seeking to enhance their sustainable development capabilities by maintaining an appropriate level of financial flexibility. This is particularly important in the context of current global economic and environmental challenges.

2. Theoretical basis and research hypothesis

2.1. Financial flexibility and corporate sustainability performance

The concept of financial flexibility was first introduced by the American scholar Myers in 1984 [4] and was later adopted by Chinese scholars, becoming widely applied in the field of corporate management. Financial flexibility refers to the ability of a business

to effectively manage its cash and cash equivalents, as well as to adjust its debt levels to optimize resource allocation, improve operational efficiency, and reduce risks [17]. Based on this capability, financial flexibility becomes a key driving factor for companies to implement sustainable development strategies. It allows companies to maintain necessary flexibility in the face of economic and environmental challenges while ensuring the efficient use of resources and the achievement of long-term strategic goals. In the pursuit of sustainable development, companies need to focus not only on economic benefits but also on environmental and social benefits, to achieve harmonious coexistence with the environment. Following the definition by Xie and Zhu [18], this study categorizes sustainable development performance into two dimensions: financial performance and environmental and social responsibility performance. Financial performance reflects the profits and revenue a company gains from its daily operations, whereas environmental and social responsibility performance focuses on the organization's initiatives and outcomes in environmental actions and adherence to social ethical standards. Examples include reducing emissions, using sustainable materials, ensuring labor practices that comply with ethical norms, and participating in community development.

Existing research reveals that financial flexibility has a significant impact on corporate sustainable development. As a key tool in strategic decision-making, financial flexibility allows companies to rapidly adapt their resource allocation and operational strategies to changes in the external environment [19]. This flexibility, stemming from effective liquidity and debt level management, enables companies to swiftly mobilize funds when faced with new opportunities or challenges [20]. Specifically, companies with higher financial flexibility are more likely to provide financial support for environmental innovation and social responsibility projects, maintaining these critical investments even during economically tight periods [21]. In terms of financial performance, financial flexibility not only allows companies to quickly seize market opportunities for investment but also to rapidly adjust in unfavorable market conditions, thus minimizing losses [22]. A concrete manifestation of this flexibility is the ability of companies to rapidly invest in efficient production technologies, enhancing efficiency and profits [23]. At the same time, it helps maintain operational stability during economic fluctuations, preventing financial crises [24]. In the long run, this capability enables companies to use capital more effectively, reduce market volatility risks, and make wiser sustainable investment decisions. In terms of environmental and social responsibility performance, financial flexibility supports companies in making necessary long-term investments, such as developing environmentally friendly products, improving working conditions, and participating in community development. These investments not only enhance a company's environmental and social performance but also contribute to building a strong corporate reputation and brand loyalty [25]. Specifically, through financial flexibility, companies can continue to advance critical projects such as energy conservation, emissions reduction, and sustainable supply chain management during periods of tight resources, thereby enhancing their performance in environmental protection and social responsibility over the long term.

Although financial flexibility can positively impact corporate sustainable development performance to some extent, according to financial flexibility theory, excessively high financial flexibility might trigger a range of deeper issues, thereby negatively affecting sustainable development performance [19,26]. On one hand, excessive financial flexibility may lead to 'adventurous behavior' in decision-making processes. This refers to a scenario where companies, possessing ample financial resources, might become overly confident and invest in high-risk projects or those with uncertain returns [10]. Such decision-making often stems from excessive optimism about market opportunities and an underestimation of risks, leading to an imbalance in resource allocation. This can reduce operational efficiency, weaken core competitiveness, and affect profitability and long-term development. On the other hand, it can also lead to overly conservative decision-making, where companies excessively rely on cash reserves and debt financing. This could slow their response to new investment opportunities or even cause them to miss important market opportunities [27]. This increases financial risk, harms innovation capabilities and market competitiveness, and impacts long-term development and market position. In terms of financial performance, excessive financial flexibility may lead to a lack of necessary prudence and risk control in investment decisions [28]. Specifically, companies might over-invest in emerging markets or innovation projects that have not been fully evaluated, neglecting the potential negative impact of these decisions on long-term financial health. This type of over-investment not only can lead to a waste of funds but also may cause a decline in long-term profitability, especially when market conditions suddenly change and the company may struggle to quickly adjust its financial strategies to new challenges. Regarding environmental and social responsibility performance, according to resource dependence theory, too much financial flexibility might lead to strategic confusion in investments in environmental protection and social responsibility [29–31]. This could manifest as a lack of long-term coherence in these areas of investment or superficial investments made in pursuit of short-term reputation, which do not effectively address fundamental environmental and social issues. Furthermore, overly diversified financial resources might prevent sustained investment in important environmental and social responsibility projects, thus affecting the long-term performance and reputation building in these aspects [32]. Therefore, this research articulates the following hypothesis.

H1a. Financial flexibility has an inverted U-shaped effect on sustainability performance.

H1b. Financial flexibility has an inverted U-shaped effect on sustainable financial performance.

H1c. Financial flexibility has an inverted U-shaped effect on sustainable environmental social responsibility performance.

2.2. Environmental uncertainty and corporate sustainability performance

Environmental uncertainty refers to the presence and impact of unpredictable and unstable factors in a company's external environment, including market dynamics, policy changes, technological advancements, and shifts in competitive landscapes [33]. In the process of a company's sustainable development, environmental uncertainty plays a key role. It affects not only the formulation of corporate strategic decisions but also the company's ability to respond to market changes and effectively allocate resources. For

companies, effectively managing and adapting to this uncertainty is one of the key challenges in achieving sustainable development performance [34]. Here, sustainable development performance refers to a company's comprehensive performance across economic, social, and environmental dimensions, reflecting the overall health and responsibility of its long-term development.

Environmental uncertainty directly impacts a company's sustainable development performance. This uncertainty primarily arises from external market fluctuations, policy changes, and rapid technological advancements [35]. In such a highly uncertain environment, companies face challenges in formulating and implementing sustainable development strategies. The need to invest more resources and effort in responding to changes can reduce economic benefits [36], thereby affecting sustainable development. In terms of financial performance, environmental uncertainty can lead to fluctuations in a company's revenue and profits, increasing operational risks [37]. This is mainly because uncertainty makes market demand and the competitive environment difficult to predict, thus affecting a company's sales and profitability [38]. For instance, rapidly changing markets might force companies to frequently adjust their product lines and marketing strategies, increasing operational costs and management complexity [39]. In terms of environmental and social responsibility performance, environmental uncertainty might make companies more cautious in investing in environmental projects and social responsibility activities [40]. Due to uncertain market and policy environments, companies might delay or reduce investments in these areas, thus impacting their long-term commitment and performance in environmental protection and social responsibility [41,42]. For example, companies might reduce investment in sustainable technologies due to market instability, or cut back on support for social welfare projects under economic pressure [43]. In light of these observations, the study advances the following hypotheses.

H2a. Environmental uncertainty has a negative impact on sustainable development performance.

H2b. Environmental uncertainty has a negative impact on sustainability financial performance.

H2c. Environmental uncertainty has a negative impact on environmental social responsibility performance for sustainable development.

2.3. The moderating effect of environmental uncertainty

Environmental uncertainty plays a significant role in the relationship between financial flexibility and corporate sustainable development performance. In a rapidly changing environment, companies face factors such as market dynamics, policy changes, and technological advancements that require high adaptability and flexibility. Under such uncertainty, financial flexibility becomes a key factor for companies to respond to external changes, maintain competitiveness, and achieve sustainable development [9]. Firstly, as an external pressure, environmental uncertainty significantly impacts a company's resource allocation and strategic decision-making according to resource dependency theory [44]. Companies need to continuously assess their resource allocation strategies to ensure competitiveness and sustainability in uncertain market environments. Secondly, from the perspective of market adaptability, environmental uncertainty enhances the role of financial flexibility in a company's adaptation to market changes [45]. Companies with higher financial flexibility can adjust their business strategies and product portfolios more flexibly when market conditions change rapidly, to capitalize on emerging opportunities or minimize potential losses. This adaptability involves not only a rapid response to market opportunities but also timely strategic adjustments during market downturns to protect the company from adverse market shifts. Thirdly, according to dynamic capability theory, environmental uncertainty requires companies to develop abilities to rapidly adapt to external changes [46,47], and financial flexibility plays a key role here. It allows companies to flexibly allocate resources [48], respond quickly to market and technological changes, and also promotes necessary strategic updates and innovations amidst continuous environmental changes [49]. For example, companies may need to make swift capital investments when new technologies or market opportunities arise, and financial flexibility provides the necessary support for such rapid decisions. Lastly, environmental uncertainty increases the complexity in corporate strategic planning [50]. Financial flexibility provides companies with the flexibility to handle this complexity. In environments of high uncertainty, companies need to engage in more complex risk assessments and long-term planning. In such scenarios, financial flexibility allows companies to rapidly reallocate resources as needed to respond to emergencies or long-term market changes. Based on these considerations, the following hypotheses are advanced.

H3. Environmental uncertainty positively moderates the inverted U-shaped relationship between financial flexibility and firm sustainability performance.

2.4. The moderating effect of government grants

Government grants refer to financial support provided by the government to support specific activities or projects of enterprises [51]. These subsidies may target areas such as innovation research and development, environmental protection measures, and social responsibility projects. Government grants have a significant impact on a company's financial flexibility and sustainable development performance [52]. They provide an additional source of funding, helping companies support their long-term sustainability goals without increasing financial burden. In this context, government grants become a key external factor in a company's sustainable strategy, especially in situations of limited resources, where they can significantly enhance a company's financial capabilities and strategic flexibility.

Firstly, government grants enhance a company's financial resources, thereby strengthening its ability to cope with high market and environmental uncertainty [24]. This is not only a direct enhancement of financial flexibility but also, according to resource dependency theory, reflects a company's dependence on external key resources [53]. As a crucial resource, government grants enable

companies to maintain investments in key sustainability projects, such as environmental protection technology and social responsibility initiatives, even when facing financial challenges. The acquisition of such resources not only alleviates short-term financial pressures but also supports the long-term sustainable development goals of the company. Secondly, from the perspective of public choice theory, government grants, as a policy tool, provide financial incentives that guide companies to invest in projects beneficial to society and the environment [54]. This policy-driven incentive not only encourages companies to invest in sustainable development but also strengthens their ability to utilize financial flexibility in uncertain environments to face challenges [55]. For example, government grants for environmental technologies not only enhance a company's green innovation capabilities but also strengthen their strategies in responding to market fluctuations and environmental changes. Lastly, government grants play a key role in reducing investment risks, which is directly linked to the enhancement of a company's financial flexibility [56]. By reducing reliance on a single market or technology, government grants enable companies to more flexibly explore new market opportunities and innovation pathways. This effectively manages potential financial risks [57], providing companies with more space and capability for risk management in the face of risks and uncertainties, while also fostering innovation and sustainable development, thereby improving sustainable development performance. This risk management strategy is key for companies to maintain strategic flexibility and market competitiveness in highly uncertain environments [58]. As a consequence of these dynamics, this study posits the following hypotheses.

H4. Government grants positively moderate the inverted U-shaped relationship between financial flexibility and corporate sustainability performance.

Combining the above analysis, the research framework of this paper is shown in Fig. 1.

3. Study design

3.1. Sample and data

This study focuses on listed manufacturing companies as they are often indicative of overarching industry trends. Post the 2010 Beijing Conference, China formally articulated its 'dual-carbon' objectives within central government policy, laying the foundation over the subsequent decade for a theoretical framework that advocates for resource conservation, environmental stewardship, and ecological civilization. Given that 2011 marks the inaugural year for China's 'dual-carbon' transformation in manufacturing, and considering the data availability up to 2021, our analysis spans listed manufacturing enterprises' performance data from 2011 to 2021. We examine the interplay between financial flexibility, environmental uncertainty, government grants, and corporate sustainable development performance. For data integrity, several filters were applied to our dataset: ①Companies marked with 'ST' and '*ST' were excluded from the sample due to their potential financial instability and operational risks, which could introduce additional variables and biases into the analysis. Specifically, 'ST' indicates companies that have reported losses for two consecutive years, while '*ST' represents companies facing more severe financial issues or regulatory challenges. ② Companies failing to annually disclose CSR reports or those with missing data on key environmental variables during the sampling period are also omitted. ③ To mitigate the impact of outliers, a 1% and 99% truncation is applied to continuous explanatory variables. ④ To address potential multicollinearity, all interaction terms are centered. The final panel data set comprises 838 listed manufacturing companies, resulting in a total of 7844 research samples. Primary data sources include the CSMAR and WIND databases for listed companies. Specific data pertaining to environmental uncertainty and government grants are derived from the Juchao Information Network (http://www.cninfo.com.cn/), while sustainability performance metrics are calculated based on the Hexun.com (https://www.hexun.com/) CSR database for listed companies.

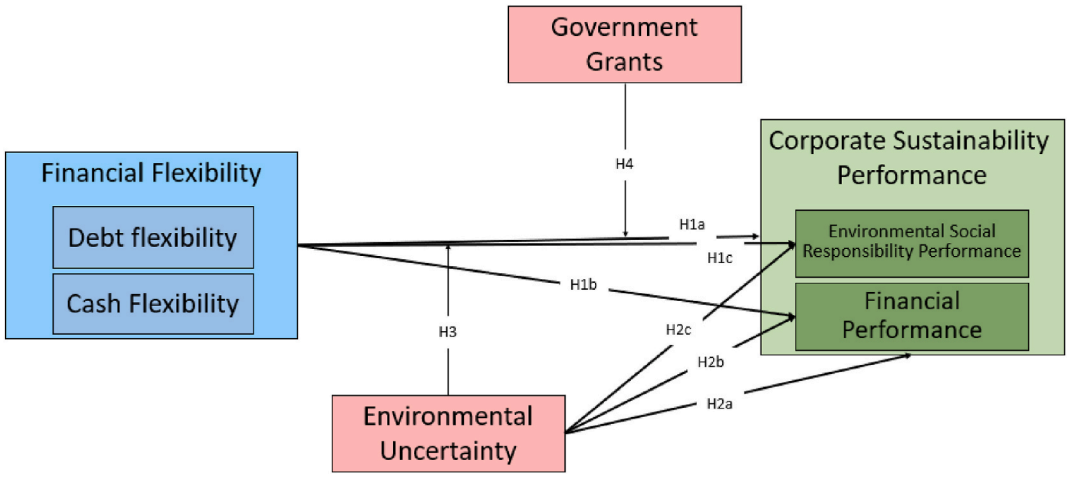

Fig. 1. Research framework.

4. Variable measurement

4.1. Explained variables

Corporate Sustainability Performance. In line with existing literature such as Ilias et al. [59] and Xie and Zhu [18], this study conceptualizes sustainability performance as a composite of two distinct dimensions: financial performance and environmental social responsibility performance. Guided by the work of Xie et al. [60], we employ Return on Total Assets (ROA) as a metric for financial performance. The ROA values are expressed as percentages [61]. Following the methodology of Jia and Liu [62], this study uses the environmental score from the Hexun.com-listed enterprises' CSR database to gauge the environmental social responsibility performance of the subject enterprises. To synthesize these two dimensions into a comprehensive measure of corporate sustainability performance, we adopt the entropy weight method [63]. The index thus obtained serves as our proxy for assessing corporate sustainability performance, as summarized in Table 1.

4.2. Explanatory variables

Financial Flexibility. Building upon existing frameworks by Zeng et al. [17] and Gong et al. [64], this study conceptualizes financial flexibility as a composite construct comprising two distinct components: financial cash flexibility and financial liability flexibility. The metric for financial cash flexibility is derived based on criteria outlined in previous studies, details of which are elaborated in Table 1. The financial liability flexibility metric also follows extant methodologies, as specified in Table 1. The sum of financial cash flexibility and financial liability flexibility provides a comprehensive measure of financial flexibility for the enterprises under study. The mathematical formulation for measuring financial flexibility is provided in Table 1 for further elucidation.

Table 1
Variable measures and data sources.

Variables	Indicators	Measurements	Literature sources	Data sources
Corporate Sustainability Performance	Combined index (CSP)	The entropy sum of Envi and Fina	Ilisa et al., 2016; Xie and Zhu,2021; Xi and Zhao,2022	Manual calculation
Environmental Performance for Sustainable Development	Corporate Environment Score (Envi)	CSR Indicator Rating Score	Jia and Liu,2014	Hexun Database
Sustainable Development Financial Performance	Total Return on Assets (Fina)	(EBIT*2)/(Total assets at the beginning of the period + Total assets at the end of the period) × 100%	Xie et al., 2016; Shao and Lv,2015	CSMAR Database
Financial Flexibility	Composite index (FF)	Sum of cash flexibility and debt flexibility, where cash flexibility = corporate cash holding ratio - industry cash holding ratio; debt flexibility = Ma x (0, industry average gearing ratio - corporate gearing ratio)	Zeng et al., 2013; Gong et al., 2022	CSMAR Database
Environmental Uncertainty	Coefficient of variation of enterprise operating income (EU)	(Standard deviation of abnormal sales revenue over the past five years/Mean of normal sales revenue over the past five years)/Industry EU median	Ghosh and Olsen, 2009; Shen et al., 2012	CSMAR Database and Corporate Annual Reports
Government Grants	Government grants (GG)	Government grants/Total assets	Kong et al., 2013	CSMAR Database and Corporate Annual Reports
Enterprise size	Enterprise size (Size)	Natural logarithm of total assets	Xu et al., 2017	WIND Database
Number of companies	Number of companies (Numb)	Natural logarithm of the total number of employees	Xu et al., 2017	WIND Database
Number of years a company has been listed	Years on the market (Age)	Number of years from the year of listing to the year of corporate annual report	Jia and Liu,2014	WIND Database
Sales Margin	Sales Margin (Ros)	Ratio of operating profit to total operating revenue	Dong et al., 2017	WIND Database
Environmental Management Certification	Environmental Management Certification (ISO)	Is the company ISO14000 certified	Li et al., 2018	WIND Database
Independent director ratio	Independent Director Ratio (Dire)	Number of independent directors/numbers of board of directors	Yang et al., 2015	WIND Database
Nature of business	Nature of business (State)	When the enterprise is a state-owned enterprise, the value is 1, otherwise it is 0	Xi and Zhao,2022	WIND Database

4.3. Moderating variables

In line with the frameworks established by Ghosh and Olsen [65] as well as Shen et al. [66], this study adopts the coefficient of variation of business revenue as a proxy to measure environmental uncertainty faced by manufacturing enterprises. The coefficient of variation is calculated as the standard deviation of the business revenue over a specific period, divided by the mean business revenue over the same period. This metric aims to capture the relative variability and thus the unpredictability of the business revenue stream. The role of environmental uncertainty in influencing the relationship between financial flexibility and corporate sustainability performance is examined via the following equation (1):

$$sale = \alpha_0 + \alpha_1 YEAR + \varepsilon \tag{1}$$

The coefficient of variation is initially calculated as the standard deviation of the business revenue residuals over the past 5 years, divided by their mean. Here, the residual ε is the abnormal business revenue, which is the revenue that remains after removing the effects explained by the time variable YEAR. The coefficient of variation obtained above is then normalized by dividing it by the median coefficient of variation for the industry in the same year.

Government grants. Following Kong et al. [67], the ratio of the number of government grants received in the current year to the firm's ending assets for the same year is used to measure the impact of government grants.

4.4. Control variables

To ensure the robustness and reliability of the study results, various control variables related to firm-specific characteristics, organizational resources, and governance structures are included in the analysis [18]. These variables capture potential confounding effects that may otherwise distort the relationship between financial flexibility, environmental uncertainty, government grants, and corporate sustainability performance. The control variables are described below: (1) Enterprise size [68] (Size). (2) Number of people in the enterprise [68] (Numb). (3) The number of years the firm has been listed [62] (Age). (4) Profitability of sales [69] (Ros). (5) Environmental management certification (Iso).ISO14001 certification represents the greening of the company to the standards set by the social system and plays an important role in corporate performance [70]. (6) Independent director ratio (Dire). The ratio of independent directors is an important indicator of the degree of corporate governance [71]. (7) Nature of the firm (State). Considering the high-dimensional heterogeneity of the nature of the firm, a dummy variable is set for the attributes of the firm [63]. (8) Time dummies are introduced to control for year-specific effects or events that might influence all firms in the sample, ensuring that any observed effects are not simply due to temporal trends. Additionally, industry dummy variables are introduced to account for inherent variations and characteristics within different sectors.

5. Model setting

In alignment with existing scholarly literature and predefined variables, we formulate two distinct regression models. The first equation (Equation (2)) is devised to investigate the prospective non-linear association between Financial Flexibility (FF) and Corporate Sustainability Performance (CSP), incorporating a quadratic term for Financial Flexibility. The equation was employed to evaluate Hypotheses H1a, H1b, and H1c. The second equation (Equation (3)) is constructed to scrutinize the potential linear—and presumably positive—impact of Environmental Uncertainty (EU) on Corporate Sustainability Performance. The equation was employed to evaluate Hypotheses H2a, H2b, and H2c.

$$\begin{aligned} CSP &= c + \alpha_1 FF_{it} + \alpha_2 FF_{it}^2 + \Sigma_i^j \eta_{i-j} Controls_{it} + \varepsilon_{it} \\ Fina &= c + \alpha_3 FF_{it} + \alpha_4 FF_{it}^2 + \Sigma_i^j \eta_{i-j} Controls_{it} + \varepsilon_{it} \\ Envi &= c + \alpha_5 FF_{it} + \alpha_6 FF_{it}^2 + \Sigma_i^j \eta_{i-j} Controls_{it} + \varepsilon_{it} \end{aligned} \tag{2}$$

$$\begin{aligned} CSP &= c + \beta_1 \mathrm{EU}_{it} + \Sigma_i^j \eta_{i-j} Controls_{it} + \varepsilon_{it} \\ Fina &= c + \beta_2 \mathrm{EU}_{it} + \Sigma_i^j \eta_{i-j} Controls_{it} + \varepsilon_{it} \\ Envi &= c + \beta_3 \mathrm{EU}_{it} + \Sigma_i^j \eta_{i-j} Controls_{it} + \varepsilon_{it} \end{aligned} \tag{3}$$

In this refined equation, c denotes the constant term, while α, β, and η serve as the regression coefficients for Financial Flexibility (FF), Environmental Uncertainty (EU), and the control variables, respectively. The expression $\Sigma_i^j \eta_{i-j} Controls_{it}$ captures the aggregated impact of additional control variables that are not explicitly presented in the equation. Here, i indexes the various manufacturing enterprises under study, t represents the time dimension (in years), and ε constitutes the random error term. Building upon the work of Haans et al. [72], which explored the characteristics of an inverted U-shaped curve, we propose a three-step testing procedure if an inverted U-shaped relationship between FF and Corporate Sustainability Performance (CSP) is to be confirmed. Firstly, the coefficient of the primary term for FF, α_1, should be statistically significant, while the coefficient of its quadratic term, α_2, should be significantly

negative. Secondly, the steepness of the inverted U-shaped curve should be sufficiently pronounced across the data sample, i.e., $\alpha_1+2\alpha_2 FF_{min}$ should yield a significantly positive value when FF is at its minimum, and $\alpha_1+2\alpha_2 FF_{max}$ should be significantly negative when FF is at its maximum. Lastly, the inflection point of this inverted U-shaped curve must lie within the data range under consideration.

To investigate the moderating effects of Environmental Uncertainty (EU) and Government Grants (GG) on Corporate Sustainability Performance (CSP), we introduce interaction terms between these variables and the primary and quadratic terms of Financial Flexibility (FF) into our existing regression equations. Equations (4) and (5) are used to evaluate hypotheses H3 and H4, respectively. Equations (4) and (5) are stated below:

$$CSP = c + \alpha_7 FF_{it} + \alpha_8 FF_{it}^2 + \beta_4 FF_{it} * EU_{it} + \beta_5 FF_{it}^2 * EU_{it} + \beta_6 EU_{it} + \Sigma_i^j \eta_{i-j} Controls_{it} + \varepsilon_{it} \quad (4)$$

$$CSP = c + \alpha_9 FF_{it} + \alpha_{10} FF_{it}^2 + \gamma_1 FF_{it} * GG_{it} + \gamma_2 FF_{it}^2 * GG_{it} + \gamma_3 GG_{it} + \Sigma_i^j \eta_{i-j} Controls_{it} + \varepsilon_{it} \quad (5)$$

Importantly, γ represents the regression coefficient specifically for Government Grants (GG).

6. Empirical results and analysis

6.1. Descriptive statistics and correlation analysis

Table 2 presents the descriptive statistics for the primary variables under study. The sustainable development performance of enterprises exhibits a broad range, with a minimum value of −0.959, a maximum value of 1.494, and a standard deviation of 0.263. Subcategories reveal further nuances: for environmental social responsibility performance, the minimum value is −12.03, the maximum is 82.16, and the standard deviation stands at 13.652. Similarly, for financial performance, the dataset ranges from a minimum of −0.894 to a maximum of 0.478, with a standard deviation of 0.038. The data highlights substantial heterogeneity in sustainability performance across enterprises, with environmental social responsibility exhibiting the most pronounced variability. Comparing the mean values to the dataset's extremities reveals that the manufacturing sector's overall sustainable development performance is sub-median. This observation underscores the pressing need for enhancing and optimizing sustainability competencies within enterprises.

Table 3 presents the correlation matrix for each principal variable under investigation. Notably, financial flexibility displays a statistically significant positive correlation with corporate sustainability performance, financial performance, and environmental social responsibility performance. This empirical finding corroborates the study's hypothesis, suggesting a salient impact of financial flexibility on corporate sustainability. Conversely, environmental uncertainty demonstrates a significant negative correlation with corporate sustainability performance, indicating a deteriorating effect on sustainability as environmental uncertainty escalates. Moreover, government grants exhibit a bifurcated relationship with sustainability performance: positively correlated with financial performance at the 10% significance level, but negatively correlated with environmental performance at the 1% significance threshold. This suggests that while grants may catalyze business investment, an abundance of such funding could incentivize an undue focus on economic gains at the expense of environmental stewardship. From a methodological standpoint, the Variance Inflation Factor (VIF) for all variables is below the critical threshold of 10, with an average VIF of 1.58, signifying the absence of severe multicollinearity among the variables. Furthermore, all variables successfully passed the Fisher unit root test, confirming the stationarity of the panel data and validating the appropriateness of proceeding with subsequent econometric analyses.

6.2. Baseline regression results

In Table 4, Models (1) and (2) delineate the regression outcomes for the relationship between financial flexibility and three dimensions of corporate sustainability: overall sustainability performance, environmental social responsibility performance, and

Table 2
Descriptive statistics results.

Variables	N	Mean	SD	Min	Max
CSP	7297	0.410	0.263	−0.959	1.494
Envi	7297	21.697	13.652	−12.03	82.16
Fina	7297	0.038	0.060	−0.894	0.478
FF	7297	0.106	0.188	−0.184	1.029
EU	7297	1.060	0.745	0.008	9.926
GG	7297	0.006	0.006	0.001	0.094
Size	7297	22.305	1.170	19.241	27.547
Numb	7297	8.016	1.105	3.689	12.342
Age	7297	11.323	6.586	0	30
Ros	7297	0.058	0.202	−8.156	1.424
ISO	7297	0.282	0.450	0	1
Dire	7297	0.382	0.075	0.167	0.8
State	7297	0.399	0.490	0	1

Table 3
Pearson correlation coefficient.

	CSP	Envi	Fina	FF	EU	GG	Size	Numb	Age	Ros	ISO	Dire	State
CSP	1												
Envi	0.979***	1											
Fina	0.572***	0.391***	1										
FF	0.203***	0.139***	0.352***	1									
EU	−0.043***	−0.038***	−0.043***	−0.013	1								
GG	−0.029**	−0.038***	0.021*	0.016	0.006	1							
Size	0.164***	0.180***	0.015*	−0.406***	−0.001	−0.075***	1						
Numb	0.196***	0.207***	0.054***	−0.363***	−0.020*	−0.007*	0.823***	1					
Age	−0.062***	−0.039***	−0.119***	−0.284***	−0.020*	−0.023**	0.400***	0.323***	1				
Ros	0.394***	0.272***	0.677***	0.259***	−0.017	−0.022*	0.008	0.010	−0.069***	1			
ISO	0.105***	0.115***	0.010	−0.030***	−0.011	−0.001	0.091***	0.091***	0.025**	0.005	1		
Dire	0.015	0.013	0.017	0.040***	−0.009	−0.004	−0.008	−0.030***	−0.080***	0.030**	−0.029**	1	
State	−0.001	0.034***	−0.141***	−0.205***	−0.034***	0.014	0.264***	0.242***	0.434***	−0.086***	−0.001	−0.114***	1
VIF				1.34	1.00	1.02	3.47	3.17	1.40	1.10	1.01	1.02	1.27
fisher	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable

Table 4
Regression analysis results.

Variables	CSP			Envi			Fina		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
FF	0.432*** (0.041)	0.362*** (0.038)		16.102*** (2.174)	15.330*** (2.086)		0.158*** (0.009)	0.100*** (0.007)	
FF^2	−0.317*** (0.074)	−0.511*** (0.068)		−10.362*** (3.955)	−24.036*** (3.756)		−0.141*** (0.016)	−0.099*** (0.013)	
EU			−0.011*** (0.004)			−0.537** (0.219)			−0.002** (0.001)
Size		0.102*** (0.009)	0.091*** (0.009)		5.389*** (0.501)	4.955*** (0.498)		0.009*** (0.002)	0.006*** (0.002)
Numb		−0.033*** (0.009)	−0.037*** (0.009)		−1.742*** (0.473)	−1.857*** (0.471)		−0.003* (0.002)	−0.005*** (0.002)
Age		−0.030*** (0.001)	−0.029*** (0.001)		−1.643*** (0.065)	−1.585*** (0.064)		−0.001*** (0.001)	−0.001*** (0.001)
Ros		0.356*** (0.013)	0.376*** (0.013)		11.294*** (0.739)	12.068*** (0.730)		0.165*** (0.003)	0.172*** (0.003)
ISO		0.036*** (0.013)	0.035*** (0.007)		2.212*** (0.396)	2.197*** (0.397)		−0.002 (0.001)	−0.002 (0.001)
Dire		−0.063 (0.040)	−0.064 (0.041)		−2.590 (2.215)	−2.549 (2.222)		−0.019** (0.008)	−0.021*** (0.008)
State		0.077*** (0.011)	0.077*** (0.011)		4.709*** (0.575)	4.701*** (0.601)		−0.006*** (0.002)	−0.007*** (0.002)
Cons	0.379*** (0.003)	−1.281*** (0.160)	−0.997 (0.157)	20.473*** (0.183)	−66.730*** (8.779)	−55.776*** (8.624)	0.028*** (0.001)	−0.137*** (0.030)	−0.039 (0.030)
Obs	7297	7297	7297	7297	7297	7297	7297	7297	7297
Ind_FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year_FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj-R^2	0.047	0.091	0.074	0.022	0.040	0.032	0.138	0.497	0.449
F	92.90	210.19	225.35	49.83	137.75	149.44	220.19	652.01	684.92

financial performance. These models account for industry and year fixed effects, and incorporate control variables. Notably, the adjusted R^2 values demonstrate a substantial enhancement in the explanatory power of the models. Specifically, the regression coefficients for the linear term of financial flexibility (FF) are positively significant at the 1% level across all three outcomes ($\alpha_1 = 0.432$, $P < 0.01$; $\alpha_3 = 0.158$, $P < 0.01$; $\alpha_5 = 16.102$, $P < 0.01$). Conversely, the coefficients for the quadratic term of financial flexibility (FF^2) are negatively significant at the 1% level ($\alpha_2 = -0.317$, $P < 0.01$; $\alpha_4 = -0.141$, $P < 0.05$; $\alpha_6 = -10.362$, $P < 0.01$). These findings suggest an inverted U-shaped relationship between financial flexibility and the three dimensions of corporate sustainability, providing initial empirical support for hypotheses H1a, H1b and H1c. However, it is crucial to exercise caution in interpreting these results. As outlined in the study by Haans et al. [72], for a robust verification of an inverted U-shaped relationship, it is imperative to consider not only the significance of the coefficients but also the slope characteristics at both ends of the curve and the location of the inflection point. Therefore, further refinement was undertaken in Model (2) to address these additional aspects.

$$CSP = c + \alpha_1 FF + \alpha_2 FF^2$$

$$Fina = c + \alpha_3 FF + \alpha_4 FF^2$$

$$Envi = c + \alpha_5 FF + \alpha_6 FF^2$$

The first-order derivative of the aforementioned equation provides the equation for the slope.

$$CSP' = \alpha_1 + 2\alpha_2 FF$$

$$Fina' = \alpha_3 + 2\alpha_4 FF$$

$$Envi' = \alpha_5 + 2\alpha_6 FF$$

For Corporate Sustainability Performance (CSP), the slope of the curve is positive ($0.5318 > 0$) when Financial Flexibility (FF) takes its minimum value and negative ($-0.3837 < 0$) at its maximum value. The inflection point occurs at 0.5207, which lies within the observed range of FF ($FF_{min} = -0.1838$, $FF_{max} = 1.0291$). Hence, the non-linear, inverted U-shaped relationship between FF and CSP is validated, confirming hypothesis H1a. For Financial Performance (Fina), the curve also presents an inverted U-shaped relationship. Specifically, the slope is $0.1455 > 0$ at FF_{min} and $-0.0953 < 0$ at FF_{max}. The inflection point is 0.5492, also within the FF range, thus confirming hypothesis H1b. For Environmental Social Responsibility Performance (Envi), the curve's slope is $22.6243 > 0$ at the minimum FF and $-16.6602 < 0$ at the maximum FF. The inflection point is 0.5147, situated within the bounds of the FF range. This establishes the non-linear, inverted U-shaped relationship between FF and Envi, confirming hypothesis H1c. In addition, this study also conducted tests using a cubic term model and found that the cubic term results were not significant. This further verifies the robustness of the inverted U-shaped results. Before the inflection points, an increase in FF correlates with improvements in CSP, Fina, and Envi, revealing a sequential amplification effect. However, after the inflection points, the consequences of either underinvestment or overinvestment owing to high levels of FF result in inefficient resource allocation. This inefficiency causes declines in CSP, Fina, and Envi, manifesting a sequential inhibitory effect. Currently, the mean FF value for China's manufacturing sector is 0.106, placing it before the inflection point and signifying that, on average, the industry is still in a phase of sustainable growth.

Model (3) in Table 4 delineates the impact of Environmental Uncertainty (EU) on Corporate Sustainability Performance (CSP), Financial Performance (Fina), and Environmental Social Responsibility Performance (Envi). Specifically, the regression coefficients for EU across all dimensions are both negative and statistically significant ($\beta_1 = -0.011$, $P < 0.01$; $\beta_2 = -0.002$, $P < 0.05$; $\beta_3 = -0.537$, $P < 0.05$). This empirical evidence corroborates a negative association between environmental uncertainty and various facets of corporate sustainable performance, thus validating hypotheses H2a, H2b, H2c. Increasing levels of environmental uncertainty appear to undermine a firm's capacity for resource orchestration, i.e., the ability to integrate, configure, and reposition both internal and external resources. This diminishment adversely affects the firm's innovation capabilities and competitive advantage, thereby hindering its path toward sustainable development.

6.3. Analysis of moderating effect

This study delves further into the nuanced roles played by Environmental Uncertainty (EU) and Government Grants (GG) as moderators in the relationship between Financial Flexibility (FF) and Corporate Sustainability Performance (CSP). Results from these moderation analyses are elaborated in Table 5. When contrasted with the R^2 value from Model (2) in Table 4, where CSP is the dependent variable, an enhancement in R^2 is evident in Table 5. This heightened R^2 suggests an optimized model and substantiates the inclusion of moderating variables along with their interactive terms. In Table 5, the coefficients associated with the linear terms of FF are positively significant, and the coefficients related to its quadratic terms are negatively significant. These results reaffirm the validity of Hypothesis H1a. More crucially, the interaction term between FF and EU (FF*EU) is positively significant with a coefficient of $\beta_4 = 0.154$, $p < 0.01$, while its quadratic interaction term (FF^2*EU) registers a negatively significant coefficient ($\beta_5 = -0.329$, $p < 0.01$). These outcomes provide initial empirical support to the notion that Environmental Uncertainty exercises a positive moderating influence on the inverted U-shaped relationship between FF and CSP. Additionally, the interaction term FF*GG manifests a positively significant coefficient ($\gamma_1 = 21.569$, $p < 0.01$), and its quadratic interaction term FF^2*GG yields a negatively significant coefficient (γ_2

$= -46.450$, $P < 0.01$). These data preliminarily corroborate that Government Grants also exert a positive moderating effect on the inverted U-shaped relationship between FF and CSP. In summary, the study furnishes nuanced academic insights into the conditional effects of Environmental Uncertainty and Government Grants on the complex relationship between Financial Flexibility and Corporate Sustainability Performance. These findings not only contribute to the existing body of literature but also have practical implications for policymaking and strategic corporate decision-making.

To provide additional empirical support for the presence of moderating effects, the study initially investigates shifts in the location of the inflection point. To facilitate the calculation of this inflection point, Regression Models (4) and (5) are systematically simplified.

$$CSP = c + \alpha_7 FF + \alpha_8 FF^2 + \beta_4 FF * EU + \beta_5 FF^2 * EU_{it} + \beta_6 EU$$

$$CSP = c + \alpha_9 FF + \alpha_{10} FF^2 + \gamma_1 FF * GG + \gamma_2 FF^2 * GG + \gamma_3 GG$$

Derivation of this yields:

$$CSP' = \alpha_7 + 2\alpha_8 FF + \beta_4 EU + 2\beta_5 FF * EU$$

$$CSP' = \alpha_9 + 2\alpha_{10} FF + \gamma_1 GG + 2\gamma_2 FF * GG$$

Then its inflection point equation can be deformed as:

$$FF = -\frac{\alpha_7 + \beta_4 EU}{2\alpha_8 + 2\beta_5 EU}$$

$$FF = -\frac{\alpha_9 + \gamma_1 GG}{2\alpha_{10} + 2\gamma_2 GG}$$

In scenarios with varying levels of environmental uncertainty and government grants, the calculated values of financial flexibility (FF) serve as inflection points in the FF-Corporate Sustainability Performance (CSP) curve. Specifically, when environmental uncertainty is low, the inflection point for FF is at 0.3307. However, under high environmental uncertainty, the inflection point shifts to 0.2889—a leftward move of 0.0419 units. Similarly, with low levels of government grants, the FF inflection point is at 0.3431, while under conditions of high government grants, it shifts to 0.2864, indicating a leftward shift of 0.0568 units. These shifts in the inflection point positions affirm the moderating effects of both environmental uncertainty and government grants on the relationship between financial flexibility and corporate sustainability performance.

To provide a more intuitive understanding of these moderating effects, Figs. 2 and 3 graphically represent these interactions, thereby offering a visual confirmation of the numerical findings.

As illustrated in Fig. 2, the curve delineating the relationship between financial flexibility and corporate sustainable development performance becomes steeper as environmental uncertainty increases. This steepening suggests that environmental uncertainty amplifies the impact of financial flexibility on sustainable development performance. Specifically, under conditions of high environmental uncertainty, moderate improvements in financial flexibility are even more beneficial for bolstering customer service and addressing external challenges sustainably. Furthermore, under heightened environmental uncertainty, the optimal value of financial flexibility decreases by 0.0419 units. This implies that firms can achieve their most favorable state for long-term sustainability with a lower degree of financial flexibility. These observations lend empirical support to Hypothesis H3.

As depicted in Fig. 3, the curve illustrating the relationship between financial flexibility and corporate sustainability performance becomes more pronounced with higher levels of government grants. This suggests that government grants amplify the relationship between financial flexibility and corporate sustainability. Specifically, in the context of substantial government funding, enterprises

Table 5
Test results on the moderating effect of environmental uncertainty and government grants.

Variables	(1)	(2)
FF	0.375*** (0.038)	0.388*** (0.039)
FF^2	−0.537*** (0.069)	−0.572*** (0.071)
FF*EU	0.154*** (0.043)	
FF^2*EU	−0.329*** (0.099)	
EU	−0.013*** (0.004)	
FF* GG		21.569*** (5.465)
FF^2* GG		−46.450*** (13.332)
GG		0.087 (0.527)
Cons	−1.281*** (0.160)	−1.286*** (0.160)
Obs	7297	7297
Controls	Yes	Yes
Ind_FE	Yes	Yes
Year_FE	Yes	Yes
Adj-R^2	0.093	0.091
F	155.13	154.64

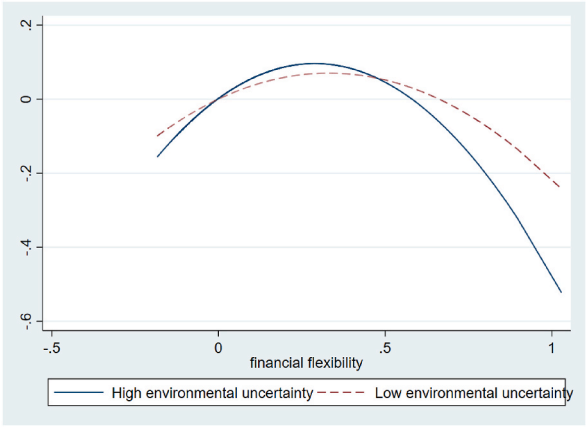

Fig. 2. Moderating effect of environmental uncertainty.

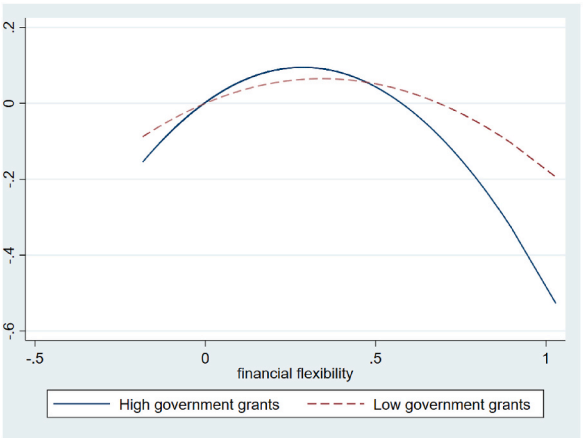

Fig. 3. Moderating effect of government grants.

are better positioned to access external capital and incentives, thereby reducing their reliance on internal resources and strategic choices. Consequently, they are more likely to invest in environmental and social activities that align with governmental objectives and societal expectations, gaining further governmental support and public recognition. Additionally, in scenarios of high government grants, the optimal level of financial flexibility diminishes by 0.0568 units, indicating that companies can achieve optimal long-term sustainability with reduced financial flexibility. These findings empirically substantiate Hypothesis H4.

All hypotheses (H1a, H1b, H1c, H2a, H2b, H2c, H3, and H4) proposed in this study were supported through thorough analysis and testing. The results of the hypothesis testing are shown in Table 6.

Table 6
Summary of hypothesis testing results.

Hypothesis	Description	Result
H1a	Financial flexibility has an inverted U-shaped effect on sustainability performance.	Supported
H1b	Financial flexibility has an inverted U-shaped effect on sustainable financial performance.	Supported
H1c	Financial flexibility has an inverted U-shaped effect on sustainable environmental social responsibility performance.	Supported
H2a	Environmental uncertainty has a negative impact on sustainable development performance.	Supported
H2b	Environmental uncertainty has a negative impact on sustainability financial performance.	Supported
H2c	Environmental uncertainty has a negative impact on environmental social responsibility performance for sustainable development.	Supported
H3	Environmental uncertainty positively moderates the inverted U-shaped relationship between financial flexibility and firm sustainability performance.	Supported
H4	Government grants positively moderate the inverted U-shaped relationship between financial flexibility and corporate sustainability performance	Supported

7. Endogeneity and robustness tests

7.1. Endogeneity test

In this study, to address the potential endogeneity issue between financial flexibility and corporate sustainability performance, control variables have been incorporated into the model. To further mitigate the impact of endogeneity arising from reverse causality, we employ the instrumental variable (IV) method to scrutinize the relationship between financial flexibility and corporate sustainability performance. In this study, the average financial flexibility of firms within the same province is employed as an instrumental variable. This choice is driven by the positive correlation between the average financial flexibility of firms in a given province and the idiosyncratic characteristics of each individual firm, while maintaining a lesser correlation with the innovation decisions of individual firms [73]. Initially, the Sargan statistic is significant at the 1% statistical level, signaling that the financial flexibility variable indeed confronts a notable endogeneity problem and affirming the validity of the instrumental variable. Subsequently, the Kleibergen-Paap rk LM statistic is significant at the 1% statistical level, with results robustly rejecting the null hypothesis of non-identifiability. Lastly, the Cragg-Donald Wald F statistic holds significance at the 1% statistical level, and its resultant values substantially reject the null hypothesis concerning the weak instrumental variable. Consequently, the employment of the average financial flexibility of enterprises within the same province as an instrumental variable is not characterized as weak, validating the rationality behind selecting this indicator for the study. Based on the IV method, endogeneity concerns are effectively addressed. The regression results, presented in Table 7, validate the robustness of our study's fundamental hypotheses. This study also rigorously assesses the robustness pertaining to endogeneity, primarily through the identification test for heteroskedasticity. Upon conducting both the BP and White tests, the presence of heteroskedasticity was confirmed. Consequently, this study employs the weighted least squares method to correct for heteroskedasticity, with the resultant findings presented in the second column of Table 7. Notably, the outcomes remain in alignment with the preceding conclusions.

7.2. Robustness tests

To further corroborate the robustness of our study's findings, we employ an alternative measure for corporate sustainability performance, using dual performance as a proxy variable based on previous literature [18]. First, both corporate financial performance and environmental social responsibility performance are standardized to range from 0 to 1. Next, we compute dual performance (Ambi) using the equation: (Ambi) = [(1-|Fina-Envi|) *$\sqrt{}$(Fina*Envi)]/1. This equation is inspired by the dual formula of Zang and Li [74]. The robustness test results, presented in Table 8, reaffirm the inverted U-shaped relationship between financial flexibility and corporate sustainability performance. Furthermore, the results confirm that environmental uncertainty and government grants exert significant positive moderating effects on this relationship, thereby lending additional empirical support to our initial hypotheses. This enhances the validity and generalizability of our study's conclusions.

Secondly, this paper employs the Tobin's Q value as a substitute for the dependent variable, grounded in the rationale that one of the objectives pursued by enterprises is to maximize shareholder value [75]. Utilizing the stock market price to reflect the market's expectations regarding the company's operations and future development trends is deemed more objective. Data is sourced from the CSMAR database. The regression results, presented in Table 8, affirm that the research findings maintain their robustness.

Lastly, this study opts to utilize the environmental information disclosure of listed companies as an alternative for the dependent variable [76]. This choice is predicated on the understanding that enterprises aiming for long-term, sustainable development will assuredly not solely prioritize profit but will also consider environmental and social responsibilities. A value of 1 is assigned when a listed company discloses environmental-related information, and 0 otherwise, with data derived from the CSMAR database. Given that this substitution renders the dependent variable discrete, a binary Logit model is selected for regression analysis. The regression results are presented in Table 8.

Table 7
Regression analysis of endogeneity tests.

Variables	instrumental variable	WLS
FF	2.192*** (0.407)	1.225*** (0.145)
FF^2	−1.138* (0.682)	−1.773*** (0.576)
Size	0.108*** (0.018)	0.020*** (0.004)
Numb	0.077*** (0.011)	0.035*** (0.004)
Age	0.001 (0.001)	−0.004*** (0.001)
Ros	−0.008 (0.096)	0.489*** (0.013)
ISO	0.052*** (0.010)	0.049*** (0.006)
Dire	−0.060 (0.062)	0.033 (0.036)
State	0.052*** (0.013)	0.015** (0.006)
Cons	−2.853*** (0.471)	−0.454*** (0.069)
Obs	7297	7297
Ind_FE	Yes	Yes
Year_FE	Yes	Yes
Adj-R^2	0.227	0.244
F	810.55	261.88

Table 8
Regression analysis of robustness tests.

Variables	Ambi			Tobin Q			Corporate environmental information disclosure		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
FF	18.340*** (2.754)	19.318*** (2.762)	19.503*** (2.809)	0.661*** (0.164)	0.690*** (0.165)	0.741*** (0.167)	0.098* (0.055)	0.108** (0.055)	0.116** (0.055)
FF^2	−17.255*** (4.935)	−18.389*** (4.940)	−19.575*** (5.205)	−2.665*** (0.296)	−2.726*** (0.297)	−2.922*** (0.308)	−0.563*** (0.098)	−0.583*** (0.099)	−0.611*** (0.102)
FF*EU		10.052*** (3.142)			0.338* (0.185)			0.114* (0.062)	
FF^2*EU		−13.639* (7.253)			−0.787* (0.427)			−0.256* (0.142)	
EU		−0.510* (0.299)			−0.001 (0.018)			0.001 (0.006)	
FF* GG			847.871** (395.25)			44.471* (23.666)			13.566* (7.862)
FF^2* GG			−1636.874* (980.939)			−158.588*** (57.718)			−34.876* (19.180)
GG			104.910*** (37.109)			−3.255 (2.283)			0.546 (0.759)
Cons	−49.634*** (11.615)	−49.036*** (11.573)	−50.406*** (11.595)	11.621*** (0.691)	11.511*** (0.690)	11.533*** (0.690)	−0.369*** (0.230)	−0.401*** (0.229)	−0.409*** (0.229)
Obs	7297	7297	7297	7297	7297	7297	7297	7297	7297
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind_FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year_FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj-R^2	0.157	0.161	0.160	0.121	0.121	0.122	0.08	0.08	0.08
F	138.41	102.53	102.09	45.09	33.13	33.67	160.89	117.37	117.46

8. Further research

To delve deeper into the nuances of how financial flexibility impacts corporate sustainability performance across manufacturing companies of varying ownership structures, this study segregates the sample into two distinct groups. Enterprises characterized by a 'nature' variable of 1 are categorized as state-owned enterprises, while those with a 'nature' variable of 0 are considered non-state-owned enterprises. This classification enables us to scrutinize the optimal financial flexibility thresholds for manufacturing enterprises of different ownership types, thereby providing data-driven insights to inform tailored sustainable development strategies for these entities. According to the regression outcomes presented in Table 9, the inverted U-shaped relationship between financial flexibility and corporate sustainability performance is consistent across both state-owned and non-state-owned enterprises. Additionally, the data substantiate that both environmental uncertainty and government grants have a positively moderating influence on this relationship. Building upon these findings, the study proceeds to compute the optimal financial flexibility values under varying degrees of environmental uncertainty and government grants, aiming to offer more nuanced policy recommendations for enterprises with different ownership characteristics.

The analysis extends further to quantify the optimal financial flexibility values under different scenarios of environmental uncertainty and government grants, segregating between state-owned and non-state-owned enterprises. For state-owned enterprises, under low environmental uncertainty, the optimal financial flexibility (FF) value is 0.2644. This decreases to 0.2628 under high environmental uncertainty, signifying a leftward shift in the FF-CSP curve by 0.0015. Similarly, when moving from low to high government grants, the optimal FF value shifts from 0.2739 to 0.2381, indicating a leftward shift of 0.0358 on the FF-CSP curve. For non-state-owned enterprises, the data reveals a more pronounced shift. Under low environmental uncertainty, the optimal FF value is 0.5012, which drops significantly to 0.3807 under high environmental uncertainty—a leftward shift of 0.1205. Regarding government grants, the optimal FF value decreases from 0.5291 under low grants to 0.3912 under high grants, indicating a leftward shift in the FF-CSP curve by 0.1380. These findings suggest that both types of enterprises experience a shift in the optimal level of financial flexibility when exposed to higher levels of environmental uncertainty and government grants. However, non-state-owned enterprises display a more substantial shift, which could imply they are more sensitive to these variables. This nuanced understanding of how environmental factors and government grants interact with financial flexibility across different ownership structures provides actionable insights for policy formulation and strategic planning aimed at enhancing corporate sustainability.

9. Conclusion and insights

9.1. Research findings

In an era marked by economic shifts, this study meticulously navigates through the complex relationship between financial flexibility and corporate sustainability performance, leveraging empirical data from Chinese manufacturing firms listed from 2011 to 2021. It brings to light invaluable insights and practical implications for enhancing corporate sustainability strategies, while being firmly rooted in existing literature and theoretical frameworks. Through employing multiple regression analyses, the research validates a series of models and hypotheses, with the principal takeaways as follows:

This study verified the hypothesis of an inverted U-shaped relationship between financial flexibility and corporate sustainable development performance, financial performance, and environmental and social responsibility performance (H1a, H1b, H1c). Specifically, before reaching a certain threshold, financial flexibility has a positive impact on the aforementioned performances. However, once this threshold is exceeded, these positive effects start to diminish and can even turn into negative impacts. This suggests that while financial flexibility aids companies in responding to market changes and investing in sustainable development projects, excessive financial flexibility may lead to resource wastage and reduced management efficiency. This conclusion partially affirms the findings of

Table 9
Regression results of firm nature.

Variables	State-owned enterprises			Non-State-Owned Enterprises		
	(1)	(2)	(3)	(1)	(2)	(3)
FF	0.304*** (0.076)	0.335*** (0.077)	0.330*** (0.077)	0.568*** (0.035)	0.576*** (0.035)	0.589*** (0.036)
FF^2	−0.557*** (0.176)	−0.631*** (0.182)	−0.617*** (0.178)	−0.501*** (0.067)	−0.519*** (0.067)	−0.556*** (0.072)
FF*EU		0.231*** (0.088)			0.142*** (0.048)	
FF^{2}*EU		−0.442* (0.257)			−0.315*** (0.105)	
EU		−0.012 (0.009)			−0.013*** (0.004)	
FF* GG			28.256*** (9.360)			12.443* (6.863)
FF^{2}* GG			−65.306** (25.756)			−33.090** (15.791)
GG			−0.609 (0.855)			−0.878 (0.596)
Cons	−1.587*** (0.286)	−1.585*** (0.286)	−1.566*** (0.286)	−0.713*** (0.094)	−0.713*** (0.094)	−0.697*** (0.095)
Obs	2909	2909	2909	4388	4388	4388
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Ind_FE	Yes	Yes	Yes	Yes	Yes	Yes
Year_FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj-R^2	0.108	0.111	0.108	0.130	0.131	0.129
F	107.5	79.49	79.25	129.94	95.24	94.91

Teng [21]and others, who analyzed data from companies listed on the Taiwan Stock Exchange and concluded that financial flexibility positively impacts corporate sustainability. Building upon this, our study constructs a nonlinear model to further elucidate the relationship between these two factors. In terms of financial performance, excessive financial flexibility might result in overly risky investment decisions or a lack of necessary prudence. This conclusion not only broadens the empirical study of Erdo and Bilyay (2019) on the positive impacts of financial flexibility in Poland, Russia, and Turkey [22] but also provides solid support for the hypothesis proposed in this study. In terms of environmental and social responsibility performance, excessive financial flexibility may lead to a lack of focus and efficiency in investments. This conclusion affirms the study by Zhang et al. [31] on the positive role of financial flexibility in Chinese listed companies' environmental and social responsibility, while further developing existing research conclusions with a long-term development perspective. These findings enrich the understanding of the role of financial flexibility in corporate sustainable development, emphasizing the complexity of financial management decisions and their significant impact on long-term development. They offer new perspectives for theoretical research, particularly in terms of the interplay between financial flexibility, resource allocation efficiency, and corporate sustainability.

The study found that environmental uncertainty negatively impacts corporate sustainable development performance, financial performance, and environmental and social responsibility performance (H2a, H2b, H2c). This indicates that in environments with high market volatility, rapid policy and technological changes, companies face more challenges that hinder their long-term sustainable development. Particularly under high environmental uncertainty, companies encounter greater difficulties in making strategic decisions, potentially leading to reduced efficiency in resource allocation and deviations in strategy implementation. This finding is consistent with results from existing literature on the impact of environmental uncertainty. Jia and Li [35] conducted a study on a sample of 72 companies from 6804 countries, finding that environmental uncertainty increases the complexity of business operations, impacts strategic planning and market positioning, and leads to a gradual decline in a company's sustainable development capabilities. Building on the existing scholarly research, this study provides a more in-depth perspective by specifically exploring the impact of environmental uncertainty on different dimensions of sustainable development. In terms of financial performance, the rapid changes in a high-uncertainty environment make it difficult for companies to accurately predict market trends and policy shifts, further increasing operational risks and impacting financial performance. This finding corroborates the conclusions of Singh [39]'s research. Regarding environmental and social responsibility performance, the instability of the environment and uncertainty of policies make it challenging for companies to develop and implement effective environmental and social responsibility strategies. This aligns with Chabowski [43]'s findings from a study of 3053 American companies. These findings highlight the significant role of environmental uncertainty in corporate resource allocation and strategic decision-making processes, offering new perspectives for theoretical research, particularly in terms of the interplay between environmental uncertainty and corporate sustainability.

The study further revealed the positive moderating effects of environmental uncertainty (H3) and government subsidies (H4) on the relationship between financial flexibility and corporate sustainable development performance. Specifically, under high environmental uncertainty, the impact of financial flexibility on sustainable development performance becomes more pronounced. This indicates that in dynamic and unstable market environments, financial flexibility is a key resource for addressing external challenges and maintaining competitiveness. This aligns with the findings of Grewal and Tansuhaj [45], who, through empirical surveys in Asia, Eastern Europe, and South America, discovered that external environmental uncertainty enhances strategic flexibility in companies, thereby improving long-term development capabilities. The presence of financial flexibility enables companies to mobilize more resources, enhancing strategic flexibility [48]. Additionally, the presence of government subsidies strengthens the impact of financial flexibility on sustainable development performance, highlighting the important role of policy support in enhancing adaptability to market changes and promoting sustainable development [55]. This conclusion resonates with the research of Pu et al. [56], who used a sample of 69 small and medium enterprises in Bangladesh to empirically study the incentivizing effect of government support on sustainable enterprise development from an innovation perspective. This study, from the viewpoint of financial flexibility, further expands the research scope, suggesting that under high government subsidies, financial flexibility can provide more financial resources for corporate innovation, ensuring the smooth implementation of innovative strategies. These conclusions not only emphasize the importance of the external environment and policy context in corporate strategy formulation but also advise managers and policymakers to consider how financial flexibility interacts with external environments and policies, and how these interactions affect long-term corporate performance. Moreover, the results of this study offer new directions for future research on the mechanisms of financial flexibility in different market and policy environments.

The research recognizes that both state-owned and non-state-owned enterprises can enhance their sustainability performance by modulating their financial flexibility. State-owned enterprises, with their systemic advantages, achieve optimal performance at relatively lower levels of financial flexibility, indicating their innate adaptive capacities and systemic advantages in handling market and environmental uncertainties. This difference between state-owned and non-state-owned enterprises might add a nuanced understanding to the Institutional Theory, shedding light on how intrinsic organizational and ownership structures can influence the interplay between financial flexibility, external factors, and sustainability performance. Additionally, the differential impact of financial flexibility on state-owned and non-state-owned enterprises' sustainability performance proposes a nuanced understanding and extension to the Institutional Theory, highlighting how intrinsic organizational structures can dictate the interplay between financial flexibility, external variables, and sustainability performance, an aspect that merits further theoretical and empirical exploration. Therefore, while this research echoes several findings from the existing literature, it simultaneously paves the way for new dialogues and inquiries within the realms of Financial Flexibility Theory and Institutional Theory, particularly in the context of varying enterprise structures and external environments.

9.2. Management insights

This study offers actionable recommendations across different stakeholders—enterprise managers, government departments, and investors—involved in the manufacturing sector. These insights aim to enhance corporate sustainability performance by optimizing financial flexibility in the face of environmental uncertainties.

First, to the managers of manufacturing enterprises. Managers should astutely navigate their capital structure, integrating both debt and equity financing [77], while also devising prudent cash reserve strategies to sustain operational fluidity during fiscal downturns. For instance, managers could consider employing a hybrid financing strategy, melding both debt and equity, to cushion their firm against market volatilities while preserving equity interests. In terms of cash reserve strategies, embedding a cyclically adaptive model, which aligns cash reserves with market phases (expansion, peak, recession, and recovery), could prove beneficial. This ensures a firm's cash reserves are not static but reflect the financial ebb and flow of market cycles, thereby safeguarding against both overextension and resource wastage. This dynamism enables adaptability to shifting business needs and cash flow intricacies. Managers should periodically reassess their investment portfolios, ensuring they mirror current market conditions and enterprise objectives, to optimize risk-adjusted returns [78]. Overindulgence or neglect of financial flexibility might either heighten financial risks or squander potential resource efficiencies. Managers must thus strike a judicious balance. Recognizing that financial flexibility is not uniform across firms, managers should weave the company's unique attributes into its sustainable development trajectory, devising bespoke strategies that resonate with its inherent characteristics.

Second, for government departments. Crafting policies requires a keen understanding of the interplay between financial flexibility, sustainable performance, and environmental uncertainty. Thoughtful incentives, such as grants, concessional loans, and tax reliefs, are instrumental in counterbalancing the impacts of environmental uncertainty and thus, nurturing corporate financial flexibility [23]. Strategic grant allocation becomes crucial here, necessitating that grants are judiciously distributed, particularly aligned with sectors pivotal for national development and those significantly impacted by environmental uncertainties [79]. For example, prioritizing enterprises in the green energy sector, which is imperative for environmental sustainability yet might be substantially affected by technological and market uncertainties. Moreover, consistency in policy-making, especially in sectors critical for economic stability and sustainability, helps mitigate challenges presented by environmental uncertainties. Enhanced collaboration platforms should be facilitated, weaving a tapestry of cooperation between enterprises and government bodies. This ensures that policy-making is inclusive, encompassing inputs from enterprise managers and aligning with the on-the-ground realities and challenges. Additionally, providing targeted support for innovation, both financial and technical, particularly for projects that resonate with national developmental goals, is paramount. This approach ensures that firms, especially those with already high financial flexibility, are not inundated with injudicious grants that could potentially derail sustainable growth and lead to misappropriation. Thus, transparency and robust market regulations further empower businesses to navigate adeptly through environmental uncertainties, shaping a future that is sustainably secure and economically viable.

Finally, for investors. The intricate relationship between financial flexibility and sustainable performance must form the bedrock upon which enterprise valuation is built, particularly for non-state-owned enterprises, which often display a pronounced reliance on financial flexibility amidst environmental uncertainties [80]. Investors, therefore, must meticulously scrutinize debt structures, cash flow management, and investment endeavors. Considering the considerable impact of the government's supportive mechanisms—such as grants and tax incentives—on an enterprise's financial flexibility and sustainability performance [81], it is paramount for investors to stay abreast of these developments. This involves shaping investment decisions with a nuanced understanding of an enterprise's financial health, the prevailing market landscape, policy frameworks, and other relevant vectors, ensuring decisions are deeply rooted in thorough diligence. Moreover, a focus on diligent assessment is pivotal, underscoring the importance of understanding how a firm navigates its debt-equity ratio or leverages governmental grants amidst environmental uncertainties. In light of eco-conscious investing, investors should prioritize firms that not only exhibit robust financial flexibility but also a steadfast commitment to environmental and social responsibility. From a risk mitigation perspective, the emphasis should be on ensuring investment portfolios are diversified across firms with varied levels of financial flexibility, serving as a safeguard against potential market volatilities. Lastly, adopting a long-term orientation is crucial. Investors, especially those eyeing manufacturing firms, should employ a perspective that encapsulates the potential future gains from present investments in financial flexibility, crafting a strategy that is both sustainable and financially prudent [61].

9.3. Shortcomings and prospects

This study reveals the mechanisms of the relationship between financial flexibility and corporate sustainable development performance, but it still has some limitations. Firstly, the sample of this study is limited to listed manufacturing companies in China, which may not fully reflect the situation in other industries or countries. This limitation could affect the generalizability of the research findings. Additionally, the study primarily focuses on specific external moderating variables, potentially overlooking other potential influencing factors.

Based on these limitations, future research can be expanded in multiple directions. Firstly, studies could be extended to different countries and industries to explore the universality and regional specificity of the impact of financial flexibility on corporate sustainable development performance. Additionally, since financial flexibility is measured by cash levels and debt levels, future research could refine the dimensions of financial flexibility for analysis, to gain a deeper understanding of its mechanisms. Thirdly, while this study focuses on specific moderating variables, future research could introduce more external factors, such as global competitiveness, digital transformation, and ESG (Environmental, Social, and Governance) performance, to enrich the understanding of the mechanisms

of financial flexibility. Finally, the impact mechanism between financial flexibility and corporate sustainable development performance is complex and variable. Future studies could further analyze these mechanisms by subdividing financial flexibility into dimensions such as cash perspective and debt perspective. They could also incorporate intermediary variables like technological innovation and environmental governance to further elucidate the impact pathways.

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No.

Data availability statement

The datasets in the study are available from corresponding author on reasonable request.

CRediT authorship contribution statement

Xiaojuan Sheng: Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Yuxiang An:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Formal analysis, Data curation.

Declaration of competing interest

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

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