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Can biodiversity risk improve firm ESG performance? Empirical evidence from China

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ABSTRACT

We examine the relationship between biodiversity risk and firm ESG performance in Chinese A-share listed companies from 2013 to 2023. We find a significantly positive relationship between biodiversity risk and firm ESG performance, and this conclusion still holds after robustness and endogeneity tests. The mechanism analysis shows that green innovation and external regulation are the main channels through which biodiversity risk promotes firm ESG performance. In addition, the effect of biodiversity risk on ESG performance is also significantly heterogeneous due to the ownership structure, the different level of industrial pollution.

1. Introduction

Biodiversity risk refers to the possibility of a reduction in biodiversity caused by human or natural factors, such as ecological damage, overexploitation and invasive species. Biodiversity risk has created significant physical and transitional risks for businesses, with global economic losses reaching an estimated $20 trillion per year (Giglio et al., 2023). Against this backdrop, public attention to corporate environmental, social and governance (ESG) has increased substantially (Xie et al., 2018; Yu et al., 2018). Besides aiming for profit maximization, companies are also anticipated to undertake social responsibility and advance sustainable development.

Effective risk management is essential for reducing the negative effects of biodiversity risk (Noss, 2000; Wintle and Lindenmayer, 2008). Moreover, investors are acknowledging the significance of environmental and social responsibility initiatives in mitigating biodiversity risk (Kalhoro and Kyaw, 2024; Ali et al., 2024). Extensive research highlights the necessity of ESG criteria in risk management and corporate valuation (Fu et al., 2023; Zhang and Lucey, 2022; He et al.,2023). For example, firms with higher ESG scores are less vulnerable to biodiversity-related risk. Besides, integrating biodiversity information disclosure into ESG reports enables investors to better assess potential ecological risks (Kopnina et al., 2024). Based on this analysis, we conclude that improving ESG performance can effectively counteract the negative impacts of biodiversity risk.

Biodiversity risk is bound to become one of the important risk factors that cannot be ignored. This paper selects Chinese A-share listed companies as research samples to explore the relationship between biodiversity risk and corporate ESG performance. There are mainly three reasons for choosing Chinese companies: Firstly, as the country with the richest biodiversity globally and the largest developing nation, China serves as a valuable reference for other developing countries in implementing ESG strategies to mitigate biodiversity risk. Secondly, China has consistently emphasized sustainable development, and the demand for ESG initiatives aligns closely with this philosophy. Issues such as climate change and ecological degradation pose significant operational risks to businesses,

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leading to increased capital market scrutiny of corporate ESG performance (Ziegler, 2022; Srivastava, 2013). In 2022, the China Securities Regulatory Commission mandated that listed firms include ESG information as a critical component of firm disclosures. Finally, China's extensive pool of listed companies, coupled with detailed financial and non-financial data, provides rich resources for empirical research (Xue et al., 2024).

The incremental academic contributions are as follows: first, we have empirically verified biodiversity risk positively affects firm ESG performance in China's capital market, thereby enriching ESG influencing factors by incorporating the dimension of biodiversity risk. This is particularly important because current research centers on climate factor and ESG (Xue et al.,2025; Yin et al.,2024); Second, when the degree of environmental uncertainty is high, enterprises typically adopt ESG practices to enhance their responsible image. This study demonstrates how companies actively adjust their ESG performance to address biodiversity risk through the lenses of green innovation and external regulation. Ultimately, we highlight the varying effects of biodiversity risk on ESG performance across different scenarios, providing a valuable guide for policymakers to develop targeted incentive policies based on the characteristics.

The remaining content is structured as follows: Section 2 presents literature review and hypotheses. Section 3 presents methods and data. Section 4 displays the empirical results. Section 5 provides further analysis, including mechanism analysis and heterogeneity tests. Finally, Section 6 concludes.

2. Literature review and research hypotheses

Enterprises exposed to biodiversity risk often encounter operational difficulties due to resource shortage, supply chain disruption and reputation damage (Li et al., 2025; Ma et al., 2024; Flammer et al., 2025), which prompts them to take risk response measures. These firms increase cash holdings in response to uncertainty (Ahmad and Karpuz, 2024). In extreme cases, these risks may significantly increase the probability of bankruptcy (Adamolekun, 2024) and stock price crashes (Liang et al., 2024). The increasing concern from stakeholders for ecological diversity conservation and sustainability has prompted firms to adjust operational strategies to offset the negative impacts of biodiversity risk. Empirical studies have shown that investors are willing to pay extra for investments that are beneficial to biodiversity conservation (Pedersen et al., 2021; Zerbib, 2022). In particular, excellent firm ESG performance can effectively reduce debt risk, relieve the company's financial constraints, alleviate information asymmetry, elevate firm overall stability, improve corporate reputation and build trust among stakeholders (Shang et al., 2025; Chen and Xie, 2022; Lian et al., 2023; Broadstock et al., 2021). Hence, we put forward the first hypothesis:

H1: Biodiversity risk positively enhances ESG performance.

When enterprises perceive external biodiversity risk, they must consider how to comply with increasingly strict regulatory requirements to maintain the legitimacy of ongoing operations, such as increasing green investment and carrying out green innovation. Albort-Morant et al. (2018) showed green innovation can improve a company's ESG performance by reducing costs and improving economic benefits. Futhermore, investing in green projects strengthens a firm's environmental and social performance, thereby improving its overall ESG ratings (Li et al.,2018). Similarly, there exists a positive correlation between green innovation and ESG performance (Liu et al., 2024; Xu et al.,2021). Hence, biodiversity risk will prompt companies to implement positive ESG strategy adjustments through green innovation.

Enterprises operating in regions with high biodiversity risk encounter heightened external pressure, which drives them to enhance ESG performance and cultivate a responsible corporate image and reputation. Media attention is an important external supervisor of capital market (Ye et al., 2024). Accounting firms usually supervise enterprises more strictly and pay more attention to environmentally friendly projects (Cheng et al., 2014). This study classifies accounting firms (whether they are Big4 or not) and media attention (MA) as external monitoring indicators. The firm's motivation for ESG participation is positively correlated with external regulation (Liu et al., 2021). Robust ESG reporting is conducive to winning the trust of stakeholders, whereas poor ESG disclosure will damage corporate reputation. Based on this, this paper proposes:

H2a: Biodiversity risk can boost ESG performance by spurring green innovation

H2b: Biodiversity risk can enhance corporate ESG performance by improving external supervision.

Heterogeneity in the nature of corporate ownership (Ren et al., 2023). SOEs usually have more resources and funds, allowing them to invest more in ecological protection projects. Additionally, the administrative pressure and social responsibilities of SOEs make them more sensitive to biodiversity risk, which contributes to higher ESG scores.

The heterogeneity of pollution level differences. Heavy polluting industries typically confront greater pressure from the government, the public, stricter environmental regulations and oversight due to their potential to damage the ecosystem (Chen et al., 2018). Therefore, engaging in ESG practices and proactively disclosing relevant positive information not only convey favorable signals about strong business performance, but also demonstrate their commitment to sustainable management. We propose:

H3a: Biodiversity risk has a greater impact on the ESG performance of SOEs.

H3b: Biodiversity risk more strongly affects ESG performance in heavy polluting industries.

3. Methods and Data

3.1. Sample Selection

The sample dataset is selected from A-share listed companies in China from 2013 to 2023 with the following preliminary processing: (1) excluding financial, ST, *ST and PT companies; (2) Excluding the samples with missing data and abnormal data; (3) Winsorizing all continuous variables at the 1% and 99% percentiles to avoid extreme values. Ultimately, we obtain 30,826 valid

observations.

Independent variable. He et al. (2024) have constructed the biodiversity risk index and biodiversity concern index[1] based on text mining techniques applied to the annual reports of listed companies in China. Hence, this paper uses the calculation results as the proxy index of biodiversity risk.

Dependent variable. For measuring ESG performance, we rely on Hua Zheng ESG ratings from Wind database, which range from 1 to 9. We take the mean as the ESG performance indicator.

Variable definitions are listed in Table 1.

Descriptive statistics are given for the relevant variables in Table 2. The ESG scores range from 1.250 to 6, which indicates that ESG scores vary greatly among different firms. In addition, the control variable results are broadly consistent with current literature.

3.2. Model specifications

Referring to existing research, this paper constructs the following regression models:

$$ESG_{it} = \alpha_0 + \alpha_1\ BioRisk_{it} + \alpha_2\ Controls_{it} + Year + Ind + \varepsilon_{it} \quad (1)$$

Specifically, ESG_{it} represents the *ESG* performance of listed company *i* in year *t*. $BioRisk_{it}$ represents the biodiversity risk confronted by company*i*in year*t*. $Controls_{it}$ constitute control variables that may affect firm ESG performance and have been incorporated into the model, including Size, Lev, ROA, Loss, Pay, Mhare, which come from CSMAR database.*Year*and *Ind*denote fixed effects for time and industry, respectively. ε_{it} representing random error terms.

For mechanism analysis, the following model is used (Chen et al.,2024):

$$ESG_{it} = \gamma_0 + \gamma_1\ BioRisk_{it} + \gamma_2\ M_{it} + \gamma_3\ BioRisk_{it} * M_{it} + \gamma_4\ Controls_{it} + Year + Ind + \varepsilon_{it} \quad (2)$$

M_{it} are the potential mechanism variables, including green innovation (GI), Media attention (MA) and accounting firms (Big4).

4. Empirical results

4.1. Benchmark regression results

The benchmark regression outcomes are encapsulated in Table 3. All estimated coefficients from columns (1) to (8) of BioRisk indicate that biodiversity risk can significantly improve the overall firm ESG performance at the 1% level whether other characteristic variables are considered. In economic terms, companies exposed to biodiversity risk experience an approximate 4.2% increase in their ESG scores. H1 has been preliminatively confirmed.

4.2. Robustness tests

4.2.1. Replacement of dependent variable

To reduce the influence of potential variable measurement errors, this study employs the Hua Zheng median ESG scores, Wind ESG, and Bloomberg ESG as proxy indicators for the dependent variables.

As shown in Table 4, we observe that biodiversity risk is positively correlated with ESG scores, suggesting that benchmark regression results are relatively reliable.

4.2.2. Replacement of independent variable

This paper also employs the biodiversity concern indexes(BioCon_freq, BioCon_cnwords, BioCon_char) from He et al. (2024) as the proxy. We note that the coefficients in Table 5 are consistently positive and significant, further confirming the reliability of the initial findings.

4.2.3. Regressions of sub-dimensions

This paper further explores whether biodiversity risk will have an impact on the three sub-dimensions E, S and G of ESG. As shown in Table 6, Different sub-dimensions show differing sensitivities to biodiversity risk. The impact on enhancing the enterprise's environmental performance is most significant. However, biodiversity risk weakens governance (G). The reasons may be as follows: (1) Corporate governance dimension mainly includes decision-making process, supervision mechanism and transparency. Enterprises need to find a balance between environmental protection and economic benefits, which increases the complexity of governance; (2) there may be lags or inconsistencies in the formulation and implementation of governance mechanism addressing corporate biodiversity risk. In summary, the corporate governance mechanism is challenging to adjust in the short term. As a result, biodiversity risk

[1] Drew upon the biodiversity dictionary constructed by Giglio et al. (2023), He et al., 2024 selected key terms such as biodiversity, ecosystem, habitat, wildlife deforestation, fauna, flora, ocean, wetland, coral, aquatic life, desertification, carbon sink, biosphere and ecosystem. If these terms occurred over twice in the report, the biodiversity risk index was marked as 1; otherwise, it was 0. They also calculated the ratio of the character count of these keywords to the total characters in the report to get the biodiversity attention index, including BioCon_freq, BioCon_cnwords and BioCon_char.

Table 1
Variable definitions table.

Type	Variable name	Variable symbol	Definition
Dependent variable	Firm ESG performance	ESG	Mean ESG scores from Hua Zheng
Independent variable	Biodiversity risk	BioRisk	If the term related to biodiversity appears in the annual report more than twice, it is assigned a value of 1, otherwise 0.From He et al,.2024
Control variables	Corporate size	Size	Natural logarithm of the total assets of the enterprise.
	Asset liability ratio	Lev	Total liabilities at the end of the period / Total assets at the end of the period.
	Return on assets	ROA	Net Income / Total Assets
	Whether the firm has a loss	Loss	If it is in the loss this year, it is assigned a value of 1, otherwise 0.
	Executive compensation level	Pay	Natural logarithm of total management compensation
	Management ownership ratio	Mshare	Total Shares Held by Management / Total Outstanding Shares
Mechism variables	Green innovation	GI	It is measured by the annual count of independently filed green utility model patents.
	Media attention	MA	The frequency of news reports about the company on online media each year divided by 100.
	Accounting firms	Big4	If companies audited by the Big 4 accounting firms,it is assigned a value of 1, otherwise 0.

Table 2
Descriptive statistical analysis.

Variable	N	Mean	SD	Min	Max
ESG	30826	4.150	0.940	1.250	6
BioRisk	30826	0.540	0.500	0	1
Size	30826	22.36	1.310	19.58	26.44
Lev	30826	0.430	0.200	0.0500	0.920
ROA	30825	0.0400	0.0700	-0.370	0.250
Loss	30826	0.130	0.330	0	1
Pay	30769	15.43	0.720	13.19	17.57
Mshare	29930	13.27	18.89	0	70.50
GI	27554	0.562	1.967	0	14
MA	30619	2.610	4.390	0.170	34.98
Big4	28978	0.065	0.247	0	1

Table 3
Baseline regression.

	(1) ESG	(2) ESG	(3) ESG	(4) ESG	(5) ESG	(6) ESG	(7) ESG	(8) ESG
BioRisk	0.132***	0.147***	0.040***	0.039***	0.044***	0.044***	0.037***	0.042***
	(0.011)	(0.012)	(0.012)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Size			0.180***	0.263***	0.232***	0.231***	0.191***	0.214***
			(0.004)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)
Lev				-1.268***	-0.911***	-0.911***	-0.886***	-0.859***
				(0.030)	(0.034)	(0.034)	(0.033)	(0.034)
ROA					2.190***	1.953***	1.680***	1.454***
					(0.091)	(0.115)	(0.116)	(0.117)
Loss						-0.072***	-0.076***	-0.079***
						(0.020)	(0.020)	(0.020)
Pay							0.141***	0.133***
							(0.009)	(0.009)
Mshare								0.597***
								(0.028)
_cons	4.078***	4.070***	0.115	-1.213***	-0.750***	-0.706***	-1.983***	-2.463***
	(0.008)	(0.008)	(0.098)	(0.099)	(0.101)	(0.102)	(0.129)	(0.132)
Ind Fixed	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	30826	30826	30826	30826	30825	30825	30768	29878
adj. R^2	0.005	0.042	0.092	0.143	0.162	0.163	0.170	0.180

Note:Standard errors in parentheses* $p < 0.1$
** $p < 0.05$
*** $p < 0.01$. (The following tables are the same)

Table 4
Robust results: Alternative ESG.

	(1) ESGmedian	(2) Wind ESG	(3) Bloomberg ESG
BioRisk	0.039***	0.086***	0.541***
	(0.012)	(0.012)	(0.140)
_cons	-2.586***	0.433***	-43.994***
	(0.139)	(0.152)	(1.948)
Controls	Yes	Yes	Yes
Ind Fixed	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes
N	29878	18378	8546
adj. R^2	0.169	0.169	0.537

Table 5
Robust results: alternative biodiversity risk.

	(1) ESG	(2) ESG	(3) ESG
BioCon_freq	0.789***		
	(0.127)		
BioCon_cnwords		1.162***	
		(0.183)	
BioCon_char			2.090***
			(0.343)
_cons	2.479***	2.473***	2.486***
	(0.131)	(0.131)	(0.131)
Controls	Yes	Yes	Yes
Ind Fixed	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes
N	29878	29878	29878
adj. R^2	0.181	0.181	0.181

Table 6
Robust results: sub-dimensions.

	(1) E	(2) S	(3) G
BioRisk	0.107***	0.082***	-0.044***
	(0.009)	(0.010)	(0.008)
_cons	2.268***	3.464***	5.319***
	(0.106)	(0.118)	(0.096)
Controls	Yes	Yes	Yes
Ind Fixed	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes
N	29872	29872	29872
adj. R^2	0.136	0.220	0.191

exerts a negative influence on governance (G).

4.2.4. Tobit regression

Tobit regression model is also employed for robustness test. The findings in Table 7 indicate that the influence of biodiversity risk on ESG performance is notably positive.

4.3. Endogeneity tests

4.3.1. Instrumental variables

The ecological imbalance of water body[2] (EIWB) is related to biodiversity risk and the ecological status of water body in different regions is affected by natural conditions which has nothing to do with the ESG practice of firms. Consequently, EIWB is introduced as an instrumental variable (IV) to further address the possible endogeneity issues.

Table 8 illustrates the results of IV methods. The F-statistic, exceeding 8.96 at the 15% level, and the p-value of the LM statistic,

[2] NH3-N is a basic project for water quality monitoring, as a proxy variable for EIWB. The higher the content, the worse the water quality.

Table 7
Robust results: Tobit regression.

	(1) ESG	(2) ESG	(3) ESG
BioRisk	0.132***	0.011	0.042***
	(0.011)	(0.011)	(0.011)
_cons	4.078***	2.426***	2.615***
	(0.008)	(0.128)	(0.138)
Controls	No	Yes	Yes
Ind Fixed	No	No	Yes
Year Fixed	No	No	Yes
N	30826	29878	29878

significant at the 1% level, both lead to the rejection of the null hypotheses about EIWB. Table 8, columns (3) demonstrates the reliability of the previous conclusion.

Additionally, the one - period lag of BioRisk (L.BioRisk) is used as the instrumental variable. As shown in columns (2) and (4) of Table 8, BioRisk's estimated coefficient is significantly positive, which validates the previous findings. Moreover, the tests for assessing the validity of the instrumental variable have passed.

4.3.2. Propensity score matching

To correct for possible sample selection bias, propensity score matching (PSM) is used to perform a re-regression[3] (Li et al.,2021). We use nearest neighbor matching with a caliper of 0.05 for 1:1 propensity score matching, including displacement. The control variables in Model (1) have been selected as covariates. The t-test results show that the equilibrium hypothesis is well met. Table 9, Column (1) indicates that the regression conclusion of the matched samples remains robust.

4.3.3. Heckman two-stage

Finally, this paper adopts the two-stage model proposed by Heckman (1979). If the value of BioRisk is 1, set it as the treatment group; otherwise, set it as the control group. BioCon_freq_Year_Ind[4] is added as the exclusivity constraint variable in the first stage. Then we add inverse Mills ratio (IMR) into the second stage model for regression (Su et al .,2024). Shown in Column (2) - (4) of Table 9, the coefficients of BioRisk and BioCon-freq are significantly positive at the level of 1%, indicating the benchmark regression results are robust after controlling for selective error.

5. Further analysis

5.1. Mechanism analysis

The result of column (1) in Table 10 points that the coefficient of GI*BioRisk is significantly positive.This means that firms with biodiversity risk can promote the transformation and application of green innovation achievements, thus improving ESG performance. H2a is verified.

Columns (3) - (4) of Table 10 illustrate the outcomes of media attention and Big4 mechanisms. Both the coefficients of MA*BioRisk and Big4*BioRisk are found to be significantly and positively correlated. This means that firms with biodiversity risk can can improve ESG performance by strengthening external supervision. H2b is verified.

5.2. Heterogeneity analysis

In table 11, Columns (1) - (2) exhibit significant differences across firm types. In SOEs, biodiversity risk plays a significantly positive role in promoting ESG performance, but not for non-SOEs. This verifies H3a.

Columns (3) - (4) of Table 11 point out the estimated coefficients both reach statistical significance at the 1% level, but the impact of corporate biodiversity risk on ESG is more pronounced when the company operates in a heavily polluting industry. Hence, the finding supports H3b.

6. Conclusions

This paper analyzes the effect of biodiversity risk on firm ESG performance in China's capital market. Firstly, the quantitative evidence identifies that biodiversity risk significantly and positively enhances the ESG performance after robustness and endogeneity tests. Additionally, green innovation and external regulation caused by biodiversity risk are the mechanisms for improving firm ESG

[3] Since the independent variable is a binary variable taking values of 0 and 1, observations with a BioRisk value of 1 are classified into the treatment group, while those with a BioRisk value of 0 are classified into the control group for PSM and Heckman two-stage analysis.

[4] the annual industry biodiversity concern index.

Table 8
IV methods.

	IV first		IV second stage	
	(1)	(2)	(3)	(4)
	BioRisk	BioRisk	ESG	ESG
EIWB	0.555***			
	(0.177)			
L.BioRisk		0.579***		
		(0.005)		
BioRisk			2.409***	0.082***
			(0.929)	(0.020)
Controls	Yes	Yes	Yes	Yes
Ind Fixed	Yes	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes	Yes
N	26700	26004	26700	26004
adj. R^2			-1.132	0.148

Table 9
PSM and Heckman two-stage regressions.

	PSM	Heckman two-stage		
	(1)	(2)	(3)	(4)
	ESG	BioRisk	ESG	ESG
BioRisk	0.054***		0.043***	
	(0.013)		(0.011)	
BioCon_freq				79.166***
				(12.686)
Biocon_freq_Year_Ind		22.855***		
		(2.490)		
IMR			0.127*	0.119*
			(0.070)	(0.070)
_cons	-2.520	-7.626	3.037***	-3.020***
	(0.149)	(0.330)	(0.337)	(0.338)
Controls	Yes	Yes	Yes	Yes
Ind Fixed	Yes	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes	Yes
N	23653	29878	29878	29878
adj. R^2	0.176	0.178	0.180	0.181

Table 10
Mechanism analysis.

	(1) ESG	(2) ESG	(3) ESG
BioRisk	0.039***	0.024*	0.033***
	(0.012)	(0.013)	(0.012)
GI	0.022***		
	(0.004)		
GI*BioRisk	0.014***		
	(0.006)		
MA		0.004*	
		(0.002)	
MA*BioRisk		0.007***	
		(0.002)	
Big4			-0.029
			(0.034)
Big4*BioRisk			0.265***
			(0.043)
_cons	2.005***	2.190***	2.136***
	(0.145)	(0.141)	(0.144)
Controls	Yes	Yes	Yes
Ind Fixed	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes
N	26700	29680	28071
adj. R^2	0.174	0.181	0.179

Table 11
Heterogeneity tests.

	(1) SOE	(2) Non-SOE	(3) Heavy-polluting	(4) Light-polluting
BioRisk	0.122***	0.016	0.077**	0.043***
	(0.019)	(0.014)	(0.037)	(0.012)
_cons	3.330***	1.653***	4.600***	2.180***
	(0.211)	(0.172)	(0.411)	(0.140)
Controls	Yes	Yes	Yes	Yes
Ind Fixed	Yes	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes	Yes
N	10820	19058	3277	26601
adj. R^2	0.243	0.162	0.225	0.179

performance. Finally, the promotional impact of biodiversity risk on corporate ESG varies significantly with different property rights and industrial pollution levels. However, this paper also has limitations. First of all, the analysis is only based on the data of Chinese listed companies, so it is still worth exploring whether the findings are applicable to companies in other economic backgrounds, policies and regulations. Secondly, this study does not involve the analysis of economic consequences, whether the improvement of ESG performance prompted by biodiversity risk can bring actual economic benefits to enterprises? The above questions are worthy of further exploration by scholars.

Author Statement

We declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed.

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.

CRediT authorship contribution statement

Tianlei Pi: Writing – review & editing, Validation, Methodology, Conceptualization. **Linke Jiao:** Writing – original draft, Validation, Project administration, Methodology, Conceptualization. **Yuhan Zhou:** Supervision, Software, Resources, Methodology, Data curation, Conceptualization. **Jin Shi:** Validation, Investigation, Conceptualization.

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Data availability

Data will be made available on request.

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