Research article

Environmental, social and governance (ESG) performance as a moderator in assessing the impact of government subsidies on underinvestment in China

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A R T I C L E   I N F O

A B S T R A C T

In recent years, underinvestment has become common among subsidised enterprises in China. Stakeholder theory asserts that environmental, social and governance (ESG) performance forces enterprises to prioritise stakeholder needs by incorporating ESG principles into business operations, which in turn influences business investment decision-making. This study examines the impact of government subsidies on firm underinvestment and whether ESG performance plays a moderating role in this direct relationship. A dataset of 17,780 firm-year observations of A-share public firms in China for the period 2011–2021 was employed, and the data were analysed using the ordinary least squares regression model, fixed-effects regression model, propensity score matching difference-in-difference model, and instrumental variable approach. These results indicate that government subsidies mitigate firm underinvestment and tend to reduce underinvestment in firms with higher ESG performance. Moreover, the findings indicate that the performance in ESG factors influences the effect of government subsidies on the lack of investment in state-owned enterprises (SOEs), as opposed to non-SOEs. This effect is more noticeable in heavily polluting industries compared to non-heavily polluting industries. These findings imply that the government should promote the ESG performance of subsidised firms to enhance their overall corporate investment efficiency.

1. Introduction

Recently, Chinese firms have experienced a unique phase of economic development, whereby enterprises face significant levels of uncertainty in their investment decisions. Firms encounter financing constraints, which significantly reduce their capability to make effective investment decisions [1]. Government subsidies are a vital source of external financing for public firms [2–4]. It allows firms to obtain financial resources and, through its positive signal of government certification, enables them to have easy access to other financial resources. Between 2011 and 2021, there was a significant increase in the amount of government subsidies for China-listed firms, from 55.28 billion in 2011 to 220.5 billion[1] in 2021. However, in recent years, inefficient investment decisions among subsidised companies have increased at an alarming rate [Fig. 1], resulting in a prevalent underinvestment scenario. Underinvestment occurs in

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most Chinese firms because of funding limitations [5], financial resource restrictions [6], and stringent, challenging, and uncertain business environments [7]. As effective investment decisions are essential for firms' future development and growth [8], it is crucial to alleviate underinvestment in China and increase the effectiveness of corporate investments.

Recently, listed Chinese companies have been paying considerable attention to their ESG performance. The number of independent ESG reports increased to 63.66 %, from 886 in 2018 to 1,450 in 2022.[2] This is because of rapid economic development in China, which has resulted in increasing social and environmental issues [9], such as pollution, food safety, and environmental sustainability [10]. The concept of ESG performance requires firms to consider stakeholders' needs by integrating ESG performance into their business operations [11], which directly impacts firms' investment decisions [10,11].

Since the 18th Communist Party of China (CPC) National Congress, the Chinese government has actively promoted green financial systems. In June 2017, the State Council approved green finance reforms and the establishment of innovative pilot zones in five provinces.[3] Given that green finance has become an important direction in China's economic development, the interplay between government subsidies, firms' ESG performance, and corporate underinvestment deserves more attention. Thus, it is necessary to examine whether government subsidies affect underinvestment and whether ESG performance moderates the impact of government subsidies on firms' underinvestment. This study attempts to provide insights into the interactions among ESG performance, government subsidies, and corporate underinvestment, focusing on China's economy.

This study contributes both theoretically and practically to the extant literature in several ways. Theoretically, the existing literature focuses on the overinvestment scenario [12,13], ignoring the underinvestment scenario, which has become more prevalent among subsidised firms in recent years. In addition, this study uses signalling theory to shed light on the relationship between government subsidies and firm investment inefficiency. Although studies support the notion that ESG performance can reduce firms' financial constraints [14–16], few have specifically examined the moderating effect of ESG performance on the link between government subsidies and underinvestment. Considering China's changing external financing environment, this research gap exists, particularly within the framework of stakeholder theory. This study aims to fill a gap that has not been explored in previous research. China has become the world's second-largest economy and an important emerging market [17]. Therefore, the research findings can also be applied to other emerging economies. Hence, this study aims to provide insights into the implications of government intervention in the form of subsidies to optimise the allocation of social and corporate capital resources and rectify market inefficiency.

The paper is organised as follows: Section 2 proposes the research hypotheses based on prior literature and theories; Section 3 delineates the research strategy employed in this study, and the methods utilised for measuring the research variables; Section 4 illustrates the empirical findings and discusses the results; Section 5 presents the conclusions of the study, as well as suggestions for future research.

2. Literature review and hypotheses development

2.1. Theoretical background

2.1.1. Signaling theory

Signalling theory posits that managers with superior information can communicate positive signals about their firms' performance to investors with limited market knowledge [18]. The transmitted signal influences external investors' behaviour, and they make relevant investment decisions based on the transmission of hidden information. Thus, signal transmission can effectively alleviate information asymmetry and improve firms' investment efficiency [19,20].

Based on the tenets of signalling theory and taking into account the study context, government subsidies could be seen as a positive indication that firms have a good reputation [21,22]. This encourages investors to make positive investment decisions, thus enabling firms to secure external funding and extend their investment capacities. Hence, government subsidies help emit a positive signal about corporations' high governance, which enhances their ability to attract external investors and lowers their financial constraints [23].

2.1.2. Stakeholder theory

Stakeholder theory postulates that managers should consider stakeholders' needs when making investment decisions [24]. Managers of firms with high ESG performance are more inclined to make investment decisions that are sustainable and align with stakeholders' best interests [25]. High ESG performance serves as proof of management's commitment to meeting stakeholder demands [20,26,27]. As a result, companies with strong ESG performance tend to share ESG information with external parties. Since the government is widely seen as a significant stakeholder [28], companies with strong ESG performance are more likely to provide information related to the government to show their commitment to meeting stakeholders' expectations. Therefore, strong ESG performance improves the credibility of the signal conveyed by government support, and ESG efforts undertaken by companies enhance their reputation and are seen as a type of social capital [29]. Simultaneously, high ESG performance signifies transparent and reliable disclosures [30] as well as good sustainable development [10], thereby bolstering investors' confidence.
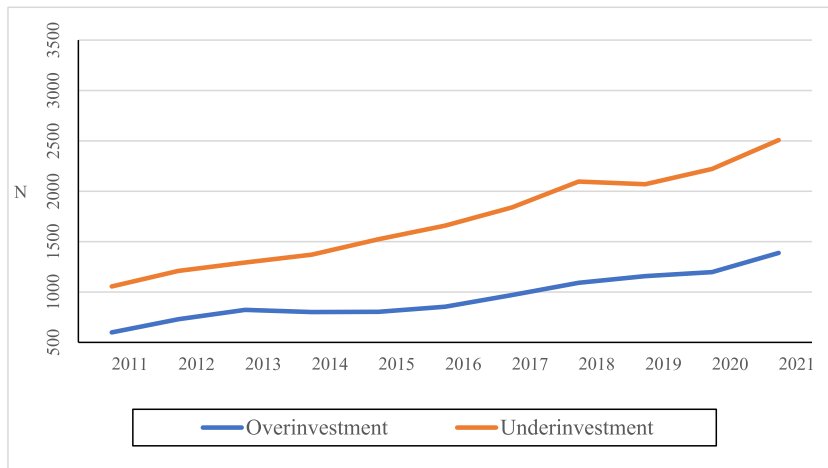
Fig. 1. Inefficient investments of subsidised firms in China.
Source: Wind database (2022).

2.2. Hypotheses development

2.2.1. Government subsidies and underinvestment

Corporate investment decisions affect domestic resources [3,31,32]. Scholars propose that government subsidies may cause agency problems [33,34] and consequently, increase the level of underinvestment among firms. The literature suggests that underinvestment originates from information asymmetry, which causes adverse selection [7,35,36], as well as agency problems [33,37]. Government requirements that accompany subsidies affect subsidy recipients' operating activities and investment behaviours. Firms may use subsidies to facilitate productive investments and endorse rent-seeking behaviour. Consequently, they may drop feasible investment projects to meet the demands of the government and authorities [4], which eventually leads to the improper use of subsidies, resulting in underinvestment.

However, by mitigating information asymmetry, studies reveal that government subsidies can reduce firms' underinvestment [3,4, 38]. As difficulties in obtaining external financing mainly cause underinvestment [39,40], government subsidies can assist firms in obtaining direct funding and overcoming capital restrictions [3,41]. Prior studies suggest that government subsidies are important external financing resources for public firms [2–4]. They reduce firm financing constraints [42] and eliminate the need to rely on financing resources with high financing costs [43].

In relation to signaling theory, previous studies indicate that government subsidies play a crucial role as a signaling mechanism. This mechanism can help to decrease information asymmetry between companies and investors, and as a result, reduce underinvestment [43,44]. Specifically, the signal of government subsidies informs outside investors that firms receiving subsidies have the ability and significant potential to generate income in the future [43]. Government subsidies are part of a company's revenue, and they directly enhance a firm's earnings. Hence, government subsidies can influence investors' evaluations of a company's financial situation [42]. Additionally, it informs external investors that subsidised firms have high-quality, non-manipulated, and disclosed information. This is because companies are subjected to intensive government scrutiny when applying for subsidies. Consequently, investors have greater confidence in subsidised firms because they perceive the information disclosed as more transparent and less asymmetric [19]. This is especially true in China, where being subsidised by the government provides a positive certification of government support. This positive signal of government certification increases the likelihood of acquiring bank loans [45] at lower financing costs, significantly reducing firms' financing constraints. Thus, the government's recognition of a corporation through subsidies typically establishes an implicit guarantee of future debt financing [42]. Furthermore, the signal transmission of government subsidies offers external investors more transparent information, and a positive government guarantees that it will efficiently reduce the imbalance in information between enterprises and external investors, thereby decreasing firms' tendency to underinvest.

Considering the direct effect of government subsidies on fund provision and the indirect effect of government guarantees, this study proposes the following hypothesis:

H1. Government subsidies have a negative impact on underinvestment.

2.2.2. Government subsidies and underinvestment: moderated by ESG performance

According to stakeholder theory, ESG requires firms to consider the needs of stakeholders and integrate them into business operations and decision-making processes in a sustainable way [11]. Firms with higher ESG performance are more likely to disclose ESG information because ESG performance represents evidence of their efforts to fulfil stakeholders' requirements [20]. Good ESG performance encourages managers to actively send positive signals to financial markets. This makes the information disclosure environment more transparent, reducing the information imbalance between enterprises and external investors and minimizing firm

underinvestment. The government is widely recognized as a significant stakeholder in various contexts [28]. Companies with strong ESG performance are inclined to disclose more details about their interactions with the government, such as whether they receive government subsidies. This disclosure implies that these firms prioritise the concerns and requirements of their stakeholders.

Furthermore, good ESG performance enhances the reliability of signals transmitted by government subsidies. Good ESG performance denotes high-quality disclosures and adequate, sustainable development [10], which consequently ameliorates investors' trust. Thus, firms' engagement in both mandated and voluntary ESG activities positively impacts their reputation and enhances their social capital. Through these ESG activities, firms demonstrate their commitment to addressing the demands and concerns of their stakeholders [29,46]. Additionally, ESG performance enhances a firm's social reputation and competitive advantage. These positive effects are delivered to stakeholders in the form of increased firm value [47]. Firms exhibiting strong ESG performance tend to display a reduced propensity to take imprudent actions because they fear their actions may ruin their reputation [14].

Thus, ESG involvement positively signals firm performance and reduces information asymmetry between firms and stakeholders. Good ESG performance provides clear evidence that managers can transmit positive GCG signals of good corporate governance and increase the credibility of the signals transmitted to external stakeholders. Therefore, we formulate the following hypothesis:

H2. ESG performance strengthens the negative relationship between government subsidies and underinvestment.

Fig. 2 depicted the research framework for this research.

3. Research design

3.1. Sample selection and data sources

This study used a sample of 17,780 observations of A-share firms in the Chinese market. The data were collected from 2011 to 2021. The rationale for choosing the period 2011–2021 is that the pattern of investment inefficiency has changed in the last ten years, whereby China has changed from being a country characterised by rapid economic growth to a country focused on achieving superior quality. Hence, the focus of investment in China shifted from quantity to efficiency over these recent 10 years [48].

The sample does not include special treatment (ST) firms, particular treatment (PT) firms, financial firms, or firms with incomplete or missing data. To mitigate the impact of outliers, the main continuous variables used in this investigation were winsorised at 1 % and 99 %. Table 1 depicts the sample composition by year, from 2011 to 2021. This study employed multiple databases to obtain the necessary data. The Wind database provides data for firms with government subsidies and was retrieved from non-operating income in the Statement of Financial Performance. Bloomberg ESG index data were used to obtain ESG performance [49,50]. For the remaining variables, data were obtained from annual reports in the China Stock Market and Accounting Research (CSMAR) database.

3.2. Research model and variable definitions

This study engages signalling and stakeholder theories as the basis of theoretical reasoning and employs several statistical models to test the hypotheses. The empirical tests consisted of two aspects. First, Equation (1) tested the influence of government subsidies on
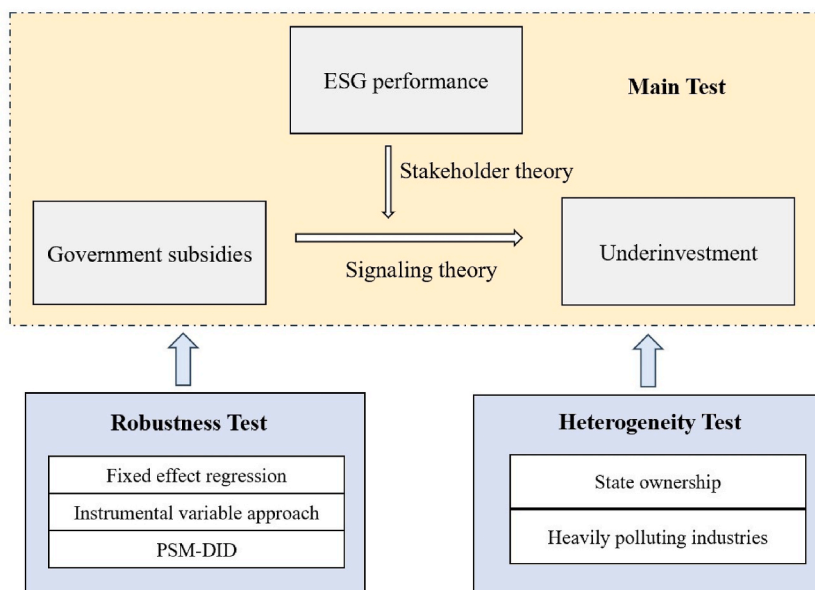

Fig. 2. Research framework.

Table 1
Sample composition by year.

Year	N	%
2011	940	5.29
2012	1,100	6.19
2013	1,198	6.74
2014	1,272	7.15
2015	1,440	8.10
2016	1,587	8.93
2017	1,756	9.88
2018	2,035	11.45
2019	2,002	11.26
2020	2,130	11.98
2021	2,320	13.05
Total	**17,780**	**100**

underinvestment. Equation (2) examined the moderating effect of ESG performance on the relationship between government subsidies and underinvestment. The coefficients of the underinvestment model were tested using t-statistics calculated based on clustered standard errors at the firm level.

$$Under\_INVB_{i,t} = \beta_0 + \beta_1 lnSub_{i,t} + \beta_2 Controls + \sum Industry + \sum Year + \varepsilon_{i,t} \tag{1}$$

$$Under\_INVB_{i,t} = \beta_0 + \beta_1 lnSub_{i,t} + \beta_2 lnESG_{i,t} + \beta_3 lnSub_{i,t} * lnESG_{i,t} + \beta_4 Controls + \sum Industry + \sum Year + \varepsilon_{i,t} \tag{2}$$

In this study, underinvestment ($Under\_INVB_{i,t}$) was measured using the [51] model, which is widely used in existing research [8, 52–54]. The model is set as follows:

$$Investment_{i,t+1} = \beta_0 + \beta_1 * SalesGrowth_{i,t} + \varepsilon_{i,t+1} \tag{3}$$

Investment refers to the net value of capital expenditure on tangible and intangible assets divided by lagged total assets. *SalesGrowth* denotes the revenue growth rate. We used residuals as a firm-specific proxy for investment inefficiency. The model in Equation (3) is estimated for each year and industry using ordinary least squares estimators. The absolute value of the negative residuals from the model in Equation (3) serves as underinvestment (*Under_INVB*), which is the dependent variable in this study. In line with [37,55], this study employed two alternative measures of investment inefficiency and compared them with the primary measure [51].

The *lnSub* represents the natural logarithm of government subsidies and *lnESG* denotes the natural logarithm of ESG scores from Bloomberg. This study adopts a variety of control factors to decrease the likelihood of omitted variables affecting underinvestment and improve the comparability of the results [55,56]. Financial leverage (*Lev*) was controlled because it affects financing constraints and investments. Firm age (*FirmAge*) was controlled for because mature firms are likely to acquire more investment opportunities because of their lower operating risks. Auditing quality (*Big4*) was also controlled for because it can transmit a positive signal of high reporting quality to other stakeholders, which reduces information asymmetry and affects investment inefficiency [26]. Ownership concentration (*Top*10) is an important factor influencing corporate investment behaviour, because a moderate concentration of equity can improve the effectiveness of firms' investments. The proportion of fixed assets (*Fixed*) was controlled for in this study because it affects firms' cash flows, which is crucial in determining investment efficiency [57]. Furthermore, this study incorporates year (*Year*) and industry (*Industry*) fixed effects as dummy variables to denote time and industry fixed effects, aiming to eliminate the effects of industry and year. The details of all variables are presented in Table 2.

Table 2
Definition of variables.

Variables	Definition	Source	Literatures
Under_INVB	Absolute value of negative residuals, calculated from Ref. [51] model.	CSMAR	[51]
Under_INVR	Absolute value of negative residuals, calculated from Ref. [55] model.	CSMAR	[55]
Under_INVC	Absolute value of negative residuals, calculated from Ref. [37] model.	CSMAR	[37]
lnSub	Natural logarithm of government subsidies from Wind database.	Wind	[58]
lnESG	Natural logarithm of ESG scores from Bloomberg.	Bloomberg	[49]
	ESG scores range from 0 to 100, and a higher score indicates a firm's higher ESG performance.		
Lev	Total liability divided by total assets.	CSMAR	[59]
FirmAge	Natural logarithm of the number of years between the year a company was founded and the current year.	CSMAR	[2]
Big4	Dummy variable, 1 for firms audited by the Big 4 auditors and 0 for otherwise.	CSMAR	[26]
Top10	The number of shares held by the top ten shareholders divided by the total number of shares.	CSMAR	[60]
Liquid	Current assets divided by current liabilities	CSMAR	[61]
Fixed	Fixed assets divided by total assets.	CSMAR	[57]

3.3. Data processing

Preliminary analyses were performed to gain an overall understanding of the data. They included descriptive and correlation analyses. Multicollinearity problems were tested using the Variance Inflation Factor (VIF), while ordinary least squares (OLS) regression methodology was utilised because it incorporated fixed effects, which were verified using Hausman tests [62]. In addition, the regression model was estimated using robust standard errors adjusted for heteroskedasticity and clustered at the firm level [63]. For robustness, we employed Propensity Score Matching Difference-in-Differences (PSM-DID) and Two-Stage Least Squares (2SLS) models to detect endogeneity.

4. Empirical results

4.1. Summary statistics

Descriptive analyses were conducted to determine the characteristics of each variable. Table 3 shows the summary statistics for all the variables. Underinvestment (*Under_INVB*) has a maximum value of 0.182 and a minimum value of nearly 0. Government subsidies (*lnSub*) were measured using the logarithm value of government subsidies and had a maximum value of 22.275 and a minimum value of 3.961, indicating that the amount of government subsidies varied significantly among the listed firms in China. For the control variables, leverage (*lev*) had a maximum value of 0.925 and a minimum value of 0.031, indicating that firms' solvency varied significantly among the listed firms in China. The ownership concentration (*Top* 10) had a mean of 0.566, indicating that Chinese listed firms' ownership concentration was moderate.

The correlation coefficients for all variables in this study are presented in Table 4. The results suggest that the association between underinvestment (*Under_INVB*) and government subsidies (*lnSub*) is significant, but with a negative coefficient of −0.12, suggesting that an increase in government subsidies can alleviate underinvestment. Moreover, ESG performance (*lnESG*) also had a negative correlation coefficient of −0.086, indicating that firms with high ESG performance experience fewer underinvestment problems. The results of all correlation coefficients were lower than 0.8, indicating that none of the correlations were very high and that multi-collinearity was not an issue in this study. In addition, the VIF value was less than 10, suggesting that there was no linear multi-collinearity in this study [64].

4.2. Regression results

The regression results for the impact of government subsidies on underinvestment and the moderating effect on ESG performance are presented in Table 5. The regression results shown in the first column revealed that there was a negative ($\beta = -0.0017$) but significant ($p < 0.05$) relationship between government subsidies (*lnSub*) and underinvestment (*Under_INVB*). Regarding whether government subsidies affect underinvestment, this result suggests that government subsidies significantly alleviate underinvestment in Chinese listed firms, supporting H1. This finding aligns with that of [3], who utilised data from the Wind database to examine the impact of government subsidies on publicly traded Chinese companies from 2007 to 2015. In accordance with signalling theory, government subsidies serve as a positive signal that conveys meaningful information to potential investors and influences their investment decisions. Government subsidies certify a firm's reputation and assist firms in securing external funding to expand their investment capacity, thereby mitigating underinvestment.

The regression findings in Column (2) reflect the results after considering the moderating effects of ESG performance. The second column of Table 5 shows the interaction term (*lnSub*lnESG*) of the moderating effect of ESG performance (*lnESG*) on the relationship between government subsidies (*lnSub*) and underinvestment (*Under_INVB*). It was significant ($p < 0.05$) and had a negative coefficient ($\beta = -0.002$). This result supports H2 and answers the research question that ESG performance moderates the relationship between government subsidies and underinvestment, implying that government subsidies are more likely to alleviate underinvestment problems in firms with high ESG performance. This means that higher ESG performance sends a positive signal to investors and strengthens

Table 3
Descriptive statistics.

Variable	Observations	Mean	SD	Minimum	Median	Maximum
Under_INVB	17,780	0.032	0.020	0.000	0.030	0.182
lnSub	17,780	16.187	1.559	3.961	16.246	22.275
Lev	17,780	0.431	0.211	0.031	0.420	0.925
FirmAge	17,780	2.929	0.323	1.386	2.996	3.611
Big4	17,780	0.052	0.222	0.000	0.000	1.000
Top10	17,780	0.566	0.151	0.199	0.570	0.910
Liquid	17,780	2.522	2.662	0.256	1.699	29.916
Fixed	17,780	0.191	0.155	0.002	0.153	0.725

Notes: Under_INVB = underinvestment based on [51] model. lnSub = natural logarithm of government subsidy. Lev = leverage, the ratio of total liability by total assets. FirmAge = natural logarithm of the number of years between the year a company was founded and current year. Big4 = 1 for firms audited by the Big 4 auditors and 0 for otherwise. Top10 = Shareholdings of Top 10 shareholders. Liquid = the ratio of current assets divided by current liabilities. Fixed = fixed assets divided by total assets.

Table 4
Correlation matrix.

Variables	1	2	3	4	5	6	7	8	9
1 *Under_INVB*	1.000								
2 *lnSub*	−0.120***	1.000							
3 *lnESG*	−0.086***	0.318***	1.000						
4 *Lev*	−0.027***	0.234***	−0.002	1.000					
5 *FirmAge*	−0.025***	0.052***	0.302***	0.173***	1.000				
6 *Big4*	−0.068***	0.211***	0.233***	0.092***	0.013*	1.000			
7 *Top10*	−0.118***	0.105***	0.168***	−0.085***	−0.174***	0.176***	1.000		
8 *Liquid*	0.031***	−0.204***	−0.069***	−0.632***	−0.180***	−0.066***	0.125***	1.000	
9 *Fixed*	0.076***	0.090***	0.043***	0.061***	0.023***	0.028***	−0.012*	−0.206***	1.000

Notes: ***, ** and * represent the significance levels at 1 %, 5 % and 10 %. Under_INVB = underinvestment. lnSub = logarithm of government subsidy. Lev = the ratio of total liability by total assets. FirmAge = logarithm of the number of years between the year a company was founded and current year. Big4 = 1 for firms audited by the Big 4 auditors and 0 for otherwise. Top10 = Shareholdings of Top 10 shareholders. Liquid = the ratio of current assets divided by current liabilities. Fixed = fixed assets divided by total assets.

Table 5
The impact of government subsidies on underinvestment.

	(1)	(2)	(3)	(4)	(5)	(6)
	Under_INVB	Under_INVB	Under_INVR	Under_INVR	Under_INVC	Under_INVC
lnSub	−0.0017***(-17.44)	−0.0014***(-8.07)	−0.0030***(-18.81)	−0.0017***(-7.95)	−0.0012***(-12.32)	−0.0009***(-5.11)
lnESG		0.0014 (1.05)		0.0018 (1.05)		0.0017 (1.15)
*lnSub*lnESG*		−0.0020***(-3.68)		−0.0023***(-3.44)		−0.0017***(-3.07)
Lev	0.0106***(11.17)	0.0086***(5.49)	−0.0101***(-6.64)	−0.0116***(-6.05)	0.0080***(8.25)	0.0066***(4.10)
FirmAge	0.0037***(7.24)	0.0018**(2.20)	−0.0079***(-9.76)	−0.0087***(-8.55)	0.0031***(5.89)	0.0009 (1.06)
Big4	−0.0013*(-1.98)	−0.0021***(-2.76)	−0.0015 (-1.45)	0.0002 (0.23)	−0.0011*(-1.68)	−0.0018**(-2.37)
Top10	−0.0103***(-10.47)	0.0011 (0.76)	0.0134***(8.65)	0.0082***(4.49)	−0.0090***(-8.92)	0.0004 (0.26)
Liquid	0.0003***(4.46)	0.0002*(1.78)	0.0007***(5.41)	0.0004**(2.40)	0.0002***(2.96)	0.0002 (1.15)
Fixed	−0.0095***(-8.43)	−0.0100***(-6.05)	−0.0001 (-0.04)	0.0025 (1.29)	−0.0089***(-7.70)	−0.0108***(-6.32)
Intercept	0.0771***(30.64)	0.0628***(11.91)	0.1018***(25.25)	0.0737***(11.03)	0.0731***(28.33)	0.0636***(11.54)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17780	6099	13082	4552	17139	5886
Adj. R^2	0.162	0.169	0.121	0.148	0.155	0.164

Notes: ***, ** and * represent the significance levels at 1 %, 5 % and 10 % respectively. Under_INVB = underinvestment based on [51] model. Under_INVR = underinvestment based on [55]. Under_INVC = underinvestment based on [37] model. LnSub = natural logarithm of government subsidy. Lev = leverage, the ratio of total liability by total assets. FirmAge = firm age, natural logarithm of the number of years between the year a company was founded and current year. Big4 = 1 for firms audited by the Big 4 auditors and 0 for otherwise. Top10 = Shareholdings of Top 10 shareholders. Liquid = liquidity, the ratio of current assets divided by current liabilities. Fixed = fixed assets divided by total assets.

the positive signalling effect of government subsidies, which assists firms in acquiring additional funding from investors, thus alleviating underinvestment. Moreover, the relationship between government subsidies (*lnSub*) and underinvestment (*Under_INVB*) remains statistically significant ($p < 0.05$) and negative ($\beta = -0.0014$), consistent with the findings of the initial regression analysis presented in Column (1) of Table 5.

The regression findings in Column (3) and Column (4) were based on underinvestment, which employed [55]. The regression findings in Columns (5) and (6) are based on the model of underinvestment proposed by Ref. [37]. The main regression results of these two methods still show a negative and significant relationship between government subsidies and underinvestment, thus supporting Hypothesis H1. The interaction term (*lnSub*lnESG*) exhibits statistical significance at the 1 % level with a negative coefficient, supporting Hypothesis H2.

Further analyses were conducted by dividing the sample into two groups based on the average amount of government subsidies. Table 6 shows that the interaction term (*lnSub*lnESG*) is significant only for firms with subsidies below the average amount. This result indicates that high ESG performance cannot strengthen the positive signalling effect of government subsidies when they exceed a certain amount.

4.3. Robustness tests

4.3.1. Fixed effect

In this study, a series of robustness tests were conducted. A fixed-effects regression was used for Equations (1) and (2) to solve the problem of omitted variables, as shown in Table 7. In addition, employing fixed effects for panel data regression can regulate unobservable heterogeneity [63]. The regression results depicted in Table 7 are consistent with the regression results of the OLS estimations (Table 5), confirming that the results are robust. Additionally, the results based on the method in Ref. [55], as shown in

Table 6
Further test: subsidy size effect.

Variables	Firms with subsidies above the average amount		Firms with subsidies below the average amount	
	(1)	(2)	(3)	(4)
	Under_INVB	Under_INVB	Under_INVB	Under_INVB
lnSub	−0.0020***(-8.93)	−0.0018***(-6.38)	−0.0019***(-9.53)	−0.0017***(-3.02)
lnESG		0.0003 (0.16)		−0.0019 (-0.54)
lnSub*lnESG		−0.0008 (-0.96)		−0.0051**(-2.34)
Lev	0.0137***(10.16)	0.0113***(6.14)	0.0076***(5.46)	0.0036 (1.17)
FirmAge	0.0029***(4.17)	0.0015 (1.61)	0.0044***(5.85)	0.0029*(1.73)
Big4	−0.0017**(-2.39)	−0.0024***(-2.98)	−0.0022 (-1.48)	−0.0008 (-0.38)
Top10	−0.0032**(-2.48)	0.0021 (1.18)	−0.0181***(-11.99)	−0.0018 (-0.61)
Liquid	0.0004***(2.99)	0.0004**(2.17)	0.0003***(3.21)	0.0001 (0.23)
Fixed	−0.0103***(-6.99)	−0.0099***(-5.29)	−0.0087***(-5.02)	−0.0085**(-2.43)
Intercept	0.0771***(17.66)	0.0740***(8.61)	0.0846***(19.42)	0.0775***(4.80)
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Observations	9204	4548	8576	1551
Adj. R^2	0.149	0.171	0.171	0.172

Notes: ***, ** and * represent the significance levels at 1 %, 5 % and 10 % respectively. Under_INVB = underinvestment based on [51] model. lnSub = natural logarithm of government subsidy. Lev = leverage, the ratio of total liability by total assets. FirmAge = firm age, natural logarithm of the number of years between the year a company was founded and current year. Big4 = 1 for firms audited by the Big 4 auditors and 0 for otherwise. Top10 = shareholdings of Top 10 shareholders. Liquid = liquidity, the ratio of current assets divided by current liabilities. Fixed = fixed assets divided by total assets.

Columns (3) and (4), and those based on the model in Ref. [37], as shown in Columns (5) and (6), are similar, thus supporting Hypotheses 1 and 2.

4.3.2. Instrumental variable (IV) approach

This study employs an instrumental variable (IV) approach to address endogeneity concerns. Following [38], this study uses a lagged variable of government subsidies (L.lnSub) as an instrumental variable for government subsidies (lnSub). The first-stage regression analysis in Column (1) of Table 8 reveals a statistically significant positive coefficient for government subsidies (lnSub). The second-stage regression analysis shown in Column (2) of Table 8 indicates that instrumented government subsidies significantly mitigate underinvestment; this finding aligns with the outcomes of the previous investigation. In the weak identification test, the value of the Kleibergen–Paap Wald rk F-statistics exceeded 10, suggesting that there was no problem with the weak instrument.

4.3.3. Tests of propensity score matching-difference in difference (PSM-DID)

This study used propensity score matching-difference in difference (PSM-DID) methodology to examine the impact of the policy of "Promoting Green Finance" approved by the State Council of China in 2017 on underinvestment. Under this policy, five provinces

Table 7
Fixed effect estimations of Equation (1) and Equation (2).

	(1)	(2)	(3)	(4)	(5)	(6)
	Under_INVB	Under_INVB	Under_INVR	Under_INVR	Under_INVC	Under_INVC
lnSub	−0.0009***(-4.92)	−0.0012***(-3.68)	−0.0007**(-2.25)	−0.0007 (-1.46)	−0.0007***(-3.36)	−0.0009***(-2.69)
lnESG		0.0026 (1.11)		0.0042*(1.70)		0.0024 (0.98)
lnSub*lnESG		−0.0015**(-2.01)		−0.0014*(-1.96)		−0.0014*(-1.94)
Lev	0.0114***(5.44)	0.0076**(2.05)	−0.0092***(-2.71)	−0.0160***(-3.62)	0.0095***(4.42)	0.0058 (1.45)
FirmAge	0.0120***(3.31)	−0.0001 (-0.02)	−0.0223***(-4.30)	−0.0131***(-2.58)	0.0091***(2.47)	−0.0053 (-1.02)
Big4	−0.0010 (-0.60)	0.0018 (0.92)	−0.0017 (-0.76)	0.0019 (0.90)	−0.0009 (-0.54)	0.0015 (0.73)
Top10	−0.0109***(-3.84)	−0.0026 (-0.59)	0.0311***(7.16)	0.0147***(2.65)	−0.0107***(-3.74)	−0.0055 (-1.19)
Liquid	0.0005***(4.33)	0.0006***(2.85)	0.0005**(2.11)	0.0004 (1.46)	0.0004***(3.08)	0.0004*(1.66)
Fixed	0.0045 (1.42)	0.0104*(1.81)	−0.0057 (-1.08)	0.0059 (0.92)	0.0033 (1.03)	0.0089 (1.47)
Intercept	0.0285***(2.78)	0.0463***(2.82)	0.0990***(6.53)	0.0630***(3.59)	0.0348***(3.30)	0.0613***(3.54)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17780	6099	13082	4552	17139	5886
Adj. R^2	0.087	0.079	0.087	0.092	0.081	0.072

Notes: ***, ** and * represent the significance levels at 1 %, 5 % and 10 % respectively. Under_INVB = underinvestment based on [51] model. Under_INVR = underinvestment based on [55] model. Under_INVC = underinvestment based on [37] model. lnSub = natural logarithm of government subsidy. Lev = leverage, the ratio of total liability by total assets. FirmAge = firm age, natural logarithm of the number of years between the year a company was founded and current year. Big4 = 1 for firms audited by the Big 4 auditors and 0 for otherwise. Top10 = Shareholdings of Top 10 shareholders. Liquid = liquidity, the ratio of current assets divided by current liabilities. Fixed = fixed assets divided by total assets.

Table 8
Instrumental variable estimation.

	(1)		(2)
	lnSub		Under_INVB
lnSub			−0.0020***(-13.63)
L.lnSub	0.7742***(132.71)		
Lev	0.4602***(8.17)		0.0097***(8.89)
FirmAge	−0.0478 (-1.55)		0.0029***(4.91)
Big4	0.2972***(7.98)		−0.0023***(-3.26)
Top10	0.4007***(6.95)		−0.0068***(-6.17)
Liquid	−0.0147***(-3.11)		0.0004***(4.37)
Fixed	−0.0944 (-1.40)		−0.0059***(-4.62)
Intercept	3.4175***(22.56)		0.0698***(21.02)
Kleibergen-Paap rk Wald F			F > 10
Firm FE	Yes		Yes
Year FE	Yes		Yes
Observations	12212		12212

Notes: ***, ** and * represent the significance levels at 1 %, 5 % and 10 % respectively. Under_INVB = underinvestment based on [51] model. LnSub = natural logarithm of government subsidies. L.lnSub = lagged variable of government subsidies, as the instrument variable of government subsidies. Lev = leverage, the ratio of total liability by total assets. FirmAge = firm age, natural logarithm of the number of years between the year a company was founded and current year. Big4 = 1 for firms audited by the Big 4 auditors and 0 for otherwise. Top10 = Shareholdings of Top 10 shareholders. Liquid = liquidity, the ratio of current assets divided by current liabilities. Fixed = fixed assets divided by total assets.

(Zhejiang, Guangdong, Guizhou, Jiangxi, and Xinjiang) were selected as the pilot provinces, and each province had its own focus and characteristics for accelerating the green finance development. A list of pilot provinces was used as the treatment group in the model, whereas a group of non-pilot provinces was used as the control group. This study first performed PSM to eliminate the selection bias issue and ensure the accuracy of the DID analysis. Various variables, such as leverage and firm age, were used as covariates. The samples were matched using the nuclear matching method, and the balance between the treated and control groups was assessed.

Table 9 presents the bias scores for the variables. The absolute value of the standard deviation decreased from the data before matching to 2 %, which satisfied the condition of not exceeding 20 % [65]. In addition, the original hypothesis that there was no systematic difference between the treated and control groups was not rejected. The P value for each variable did not pass the significance test at the 5 % level. The matching outcome was successful, which means that the PSM-DID approach can be used to estimate the model.

The PSM-DID method was used for the estimation, with some control variables added and some omitted. Table 10 presents the estimated results. The findings show that the core variable interaction term DID passes the 1 % significance level in both columns (1) and (2), indicating that the pilot provinces have fewer underinvestment problems than the non-pilot provinces, confirming the robustness of the model.

Table 9
Balance test of the PSM.

Variables	Unmatched	Mean		Bias (%)	Reduct Bias (%)	T-test	
	Matched	Treated	Control			t	P > |t|
Lev	NO	0.418	0.437	−8.9		−5.33	0.000
	YES	0.418	0.418	−0.2	97.7	−0.11	0.916
FirmAge	NO	2.908	2.938	−9.3		−5.68	0.000
	YES	2.908	2.908	0.1	99.0	0.04	0.965
Big4	NO	0.039	0.057	−8.5		−4.98	0.000
	YES	0.039	0.042	−1.5	81.9	−0.85	0.395
Top10	NO	0.571	0.564	4.5		2.73	0.006
	YES	0.570	0.572	−1.0	77.8	−0.51	0.608
Liquid	NO	2.591	2.494	3.6		2.20	0.028
	YES	2.591	2.613	−0.9	76.3	−0.44	0.657
Fixed	NO	0.175	0.198	−15.6		−9.27	0.000
	YES	0.175	0.173	1.1	93.0	0.58	0.559
Joint hypothesis		LR chi^2	p > chi^2		Mean Bias		Med Bias
Before matching		175.95	0.000		8.4		8.7
After matching		1.51	0.959		0.8		0.9

Notes: Lev = leverage, the ratio of total liability by total assets. FirmAge = firm age, natural logarithm of the number of years between the year a company was founded and current year. Big4 = 1 for firms audited by the Big 4 auditors and 0 for otherwise. Top10 = Shareholdings of Top 10 shareholders. Liquid = liquidity, the ratio of current assets divided by current liabilities. Fixed = fixed assets divided by total assets.

Table 10
The PSM-DID estimation.

Variables	(1)	(2)
	Under_INVB	**Under_INVB**
DID	−0.002***	−0.002***
	(-4.50)	(-4.47)
Lev		0.007***
		(7.43)
FirmAge		0.004***
		(7.40)
Big4		−0.003***
		(-5.38)
Top10		−0.012***
		(-12.35)
Liquid		0.000***
		(4.95)
Fixed		−0.010***
		(-8.97)
Intercept	0.057***	0.052***
	(42.94)	(24.94)
R^2	0.128	0.150
Observations	17777	17777

Notes: ***, ** and * represent the significance levels at 1 %, 5 % and 10 % respectively. Under_INVB = underinvestment based on [51] model. LnSub = natural logarithm of government subsidy. Lev = leverage, the ratio of total liability by total assets. FirmAge = firm age, natural logarithm of the number of years between the year a company was founded and current year. Big4 = 1 for firms audited by the Big 4 auditors and 0 for otherwise. Top10 = Shareholdings of Top 10 shareholders. Liquid = liquidity, the ratio of current assets divided by current liabilities. Fixed = fixed assets divided by total assets.

4.4. Heterogeneity tests

4.4.1. State ownership

The literature indicates that state-owned enterprises (SOEs) suffer from significant information asymmetry and agency issues, which potentially influence their business investment decisions [52,66]. The work [9] proposed that ESG performance can mitigate information asymmetry and agency conflicts more intensely in SOEs than in non-SOEs. Hence, the moderating effect of ESG performance on the relationship between government subsidies and underinvestment may differ for firms with distinct ownership structures. To examine the impact of government subsidies on underinvestment in the context of heterogeneous ownership structures, we re-estimate Equations (1) and (2) for SOEs and non-SOEs, as shown in Table 11. The regression analysis of the baseline model reveals a statistically significant and negative association between government subsidies (lnSub) and underinvestment (Under_INVB) for both SOEs and non-SOEs, as indicated in Columns (1) and (3). This finding suggests that government subsidies effectively mitigate underinvestment in both types of enterprise. However, the impact of ESG performance on the direct relationship between SOEs and non-SOEs varies. The interaction term (lnSub*lnESG) for underinvestment is significant in SOEs, as shown in Column (4), but not in non-SOEs, as shown in Column (2), suggesting that ESG performance can only moderate the relationship between government subsidies and underinvestment in SOEs. This finding suggests that SOEs that exhibit strong ESG performance are more inclined to effectively transmit positive signals of government subsidies to the financial market than non-SOEs with good ESG performance. This phenomenon can be attributed to the fact that SOEs exhibit greater concern about ESG activities than non-SOEs, as highlighted in Ref. [66].

4.4.2. Heavily polluting industries

Heavily polluting firms in China face greater social pressure, environmental litigation, and reputation threats [67]. Hence, heavily polluting enterprises are motivated to participate in ESG activities [10,67]. Table 12 reports the heterogeneity test results for firms in heavily polluting and non-heavily polluting industries. Heavily polluting industries were categorised according to the Industry Classification Guidelines for Listed Companies established by the China Securities Regulatory Commission in 2012. The regression findings suggest that government subsidies can reduce underinvestment in both heavily and non-heavily polluting industries. However, the regression results for the moderating effect of ESG performance, as shown in Columns (2) and (4), reveal that the moderating effect of ESG performance is more prominent among firms in heavily polluting industries.

This finding suggests that firms operating in severely polluting industries are more inclined than firms in non-heavily polluting industries to actively convey positive signals to the capital market when they exhibit good ESG performance. Because firms in heavily polluting industries are subject to stringent regulations and face more environmental risk than firms in non-heavily polluting industries [66], firms with commendable ESG performance are inclined to disclose more information. This inclination stems from the desire to enhance the reliability of signals conveyed through government subsidies. Thus, the government's subsidy signal informs external investors in heavily polluting industries that firms in those industries with good ESG performance are less likely to violate

Table 11
Heterogeneity test: state ownership.

Variables	Non-SOE		SOE	
	(1)	(2)	(3)	(4)
	Under_INVB	Under_INVB	Under_INVB	Under_INVB
lnSub	−0.0018***(-13.64)	−0.0013***(-4.80)	−0.0020***(-12.95)	−0.0015***(-6.79)
lnESG		0.0013 (0.58)		0.0011 (0.61)
lnSub*lnESG		−0.0015 (-1.58)		−0.0022***(-3.37)
Lev	0.0110***(8.78)	0.0112***(4.56)	0.0064***(4.19)	0.0048**(2.32)
FirmAge	0.0034***(5.51)	0.0025**(2.15)	0.0013 (1.28)	−0.0013 (-1.03)
Big4	−0.0023**(-2.17)	−0.0026*(-1.95)	−0.0021**(-2.50)	−0.0025***(-2.76)
Top10	−0.0146***(-11.92)	−0.0012 (-0.56)	−0.0022 (-1.31)	0.0038*(1.77)
Liquid	0.0004***(4.72)	0.0003 (1.60)	0.0003*(1.76)	0.0003 (1.27)
Fixed	−0.0151***(-9.34)	−0.0162***(-5.50)	−0.0073***(-4.50)	−0.0091***(-4.45)
Intercept	0.0783***(23.38)	0.0607***(7.35)	0.0884***(20.70)	0.0734***(10.11)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	11147	2696	6633	3403
Adj. R^2	0.140	0.146	0.216	0.207

Notes: ***, ** and * represent the significance levels at 1 %, 5 % and 10 % respectively. Under_INVB = underinvestment based on [51] model. LnSub = natural logarithm of government subsidy. Lev = leverage, the ratio of total liability by total assets. FirmAge = firm age, natural logarithm of the number of years between the year a company was founded and current year. Big4 = 1 for firms audited by the Big 4 auditors and 0 for otherwise. Top10 = shareholdings of Top 10 shareholders. Liquid = liquidity, the ratio of current assets divided by current liabilities. Fixed = fixed assets divided by total assets.

Table 12
Heterogeneity test: heavily polluting industries.

Variables	Non-heavily polluting		Heavily polluting	
	(1)	(2)	(3)	(4)
	Under_INVB	Under_INVB	Under_INVB	Under_INVB
lnSub	−0.0008***(-6.84)	0.0003 (1.40)	−0.0019***(-9.30)	−0.0016***(-5.13)
lnESG		0.0022 (1.26)		−0.0010 (-0.37)
lnSub*lnESG		−0.0012*(-1.81)		−0.0029**(-2.77)
Lev	−0.0030***(-2.88)	−0.0078***(-4.59)	0.0079***(4.07)	0.0040 (1.32)
FirmAge	0.0004 (0.77)	−0.0007 (-0.78)	0.0058***(5.09)	0.0046**(2.42)
Big4	−0.0037***(-4.71)	−0.0040***(-4.49)	−0.0010 (-0.77)	−0.0006 (-0.35)
Top10	−0.0123***(-10.61)	−0.0045**(-2.49)	−0.0138***(-6.88)	−0.0024 (-0.86)
Liquid	0.0001 (1.20)	−0.0002 (-0.92)	0.0003*(1.83)	0.0009***(2.70)
Fixed	0.0081***(6.07)	0.0110***(5.35)	−0.0025 (-1.34)	−0.0062**(-2.29)
Intercept	0.0637***(24.16)	0.0360***(5.71)	0.0661***(13.80)	0.0565***(5.52)
Year FE	Yes	Yes	Yes	Yes
Observations	13084	4264	4696	1835
Adj. R^2	0.072	0.069	0.095	0.070

Notes: ***, ** and * represent the significance levels at 1 %, 5 % and 10 % respectively. Under_INVB = underinvestment based on [51] model. LnSub = natural logarithm of government subsidy. Lev = leverage, the ratio of total liability by total assets. FirmAge = firm age, natural logarithm of the number of years between the year a company was founded and current year. Big4 = 1 for firms audited by the Big 4 auditors and 0 for otherwise. Top10 = shareholdings of Top 10 shareholders. Liquid = liquidity, the ratio of current assets divided by current liabilities. Fixed = fixed assets divided by total assets.

environmental policies. Thus, the positive signal of government subsidies for heavily polluting firms tends to suffer less from underinvestment.

5. Conclusion

This study investigated the impact of government subsidies on underinvestment and the moderating role of ESG performance on this direct relationship in the context of China's listed companies. Signalling theory postulates that government subsidies send a positive signal to the capital market, which can help firms attract more external investments [2,68]. However, studies suggest that government subsidies may cause agency problems [33], because of firms' rent-seeking behaviour, which may consequently heighten the underinvestment situation. However, the empirical results of this study indicated that government subsidies tend to mitigate firm underinvestment, supporting signalling theory. Additionally, this study found that ESG performance can strengthen the negative relationship between government subsidies and underinvestment, implying that government subsidies are more effective in reducing underinvestment among firms that exhibit superior ESG performance.

The use of several robustness tests in this study ensures that the findings are robust and that the results remain unchanged. Further tests indicated that high ESG performance could not strengthen the positive signalling effect of government subsidies when the subsidies received by firms exceeded a certain amount. A heterogeneity analysis revealed that the moderating effect of ESG performance on government subsidies and underinvestment was limited to SOEs. Non-SOEs do not show moderating effects. Additionally, the moderating role of ESG performance is more prominent in firms in heavily polluting industries than in those in non-heavily polluting industries.

The findings of this study have theoretical and practical implications. Theoretically, this study provides new evidence that supports the notion that government subsidies are a form of government certification that can reduce firm underinvestment, as suggested by signalling theory. Importantly, this study finds a positive moderating role of ESG performance in the relationship between government subsidies and underinvestment. This study recommends that the government should implement appropriate policies and regulations to create an incentive mechanism for subsidised firms to engage in ESG activities. This would improve capital allocation efficiency and support sustainable development.

This study has limitations. First, the unavailability of certain data meant that the sample was limited to listed companies in China, restricting the generalisability of the findings. To enhance the comprehensiveness and validity of future studies and achieve more complete and sensible conclusions, it is important to include non-listed companies within the research scope. Second, this study employed the overall ESG score to test the moderating role of ESG performance. Future studies may seek each element of ESG as a moderator when assessing the moderating impact of ESG performance on government subsidies and underinvestment. Additionally, this analysis concentrates primarily on the relationship between government subsidies and underinvestment, neglecting the over-investment scenario. This is mainly because underinvestment has become more prevalent in recent years, which does not fully represent the impact of government subsidies on overall investment inefficiency.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Xiaoqian Wang: Writing – original draft, Funding acquisition, Data curation. **Lian Kee Phua:** Writing – review & editing, Supervision, Project administration. **Chu Wang:** Methodology.

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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