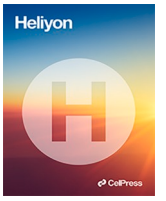
Heliyon 10 (2024) e27841

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Does green technology transformation alleviate corporate financial constraints? Evidence from Chinese listed firms

Jue Feng [a,b], Yingdong Wang [b,c,*], Wenzhi Xi [d,e]

[a] Department of Economics and Management, Yuncheng University, Yuncheng, China
[b] School of Finance, Zhongnan University of Economics and Law, Wuhan, China
[c] Strategic Studies Institute, Hubei Yangtze Labs, Wuhan, China
[d] School of Statistics and Mathematics, Zhongnan University of Economics and Law, Wuhan, China
[e] Department of Statistics, The Chinese University of Hong Kong, Hong Kong, China

ARTICLE INFO

JEL classification:
G28
G32
M21

Keywords:
Green technology transformation
Financial constraints
Green subsidies
Green credit
Synergistic effect

ABSTRACT

Green technology transformation is crucial for China to achieve its carbon peak and carbon neutrality goals. We use green transformation keywords extracted from the annual reports of listed firms to construct a green technology transformation intensity index for enterprises and investigate the impact of green technology transformation on corporate financial constraints. Our findings indicate that green technology transformation significantly mitigates corporate financial constraints, with green subsidies and debt financing as crucial mechanisms. Moreover, this effect is particularly pronounced in high-carbon-intensity industries, firms with fewer political connections, and firms affected by the carbon trading pilot. Additionally, digital and green transformations have a synergistic effect on alleviating corporate financial constraints. Therefore, we should promote the green technology transformation of enterprises and guide green finance to serve the real economy, effectively solve the financing dilemma of green enterprises, and provide strong green kinetic energy for sustainable development.

1. Introduction

Many enterprises consume resources and emit large quantities of pollutants to promote economic and social development. Traditional development patterns of high input, consumption, and pollution have caused severe resource losses and rapid deterioration of the urban environment. To counteract these adverse effects and achieve sustainable development, government entities have implemented various environmental regulations, and numerous resource-based industries have gradually undergone green transformation [1–3]. Green transformation is a vital requirement for long-term enterprise development and represents a means for China to reach its carbon peak and carbon neutrality targets [4,5]. However, the process of green transformation is often rife with instances of deceptive practices, regulatory arbitrage, and other forms of "greenwashing," which pose considerable obstacles to the full realization of green transformation [6–8].

The adoption of a green policy framework is a crucial catalyst for driving an active green transformation among enterprises, thereby playing a significant role in mitigating corporate financial constraints [9]. China's pioneering green credit and green bond initiatives have garnered global attention. They are widely regarded as effective policy tools that provide robust external financing

* Corresponding author. School of Finance, Zhongnan University of Economics and Law, 182# Nanhu Avenue, Wuhan, 430073, Hubei, China.
E-mail addresses: fengjue02@163.com (J. Feng), yingdongwang@126.com (Y. Wang), xiwenzhi1997@gmail.com (W. Xi).

https://doi.org/10.1016/j.heliyon.2024.e27841
Received 16 September 2023; Received in revised form 6 March 2024; Accepted 7 March 2024
Available online 13 March 2024

support to enterprises, underscoring the resource impact of policy dividends [10–13]. Despite numerous studies indicating the positive influence of green policy implementation on enterprises [14–16], the relationship between green transformation behavior and corporate financial constraints remains theoretical and lacks empirical evidence to substantiate it.

Achieving a comprehensive green transformation requires a focus on the number of enterprises participating in green initiatives and a concern for the quality of such efforts. Regrettably, numerous prominent enterprises ardently espouse their green image and environmental protection aspirations, yet persistently commit acts of excessive pollution or incur environmental sanctions, thereby revealing significant disparities in the efficacy of green transformation among enterprises. The root cause of this variance depends on whether firms rely on green technology for substantive transformation and upgrading. Remarkably, the existing literature rarely analyzes its impact on corporate financial constraints from the perspective of green technology transformation.

This study investigates the impact of green technology transformation on corporate financial constraints. We also explore the underlying mechanisms through which green technology transformation affects corporate financial constraints and the impact of green technology transformation on different types of businesses. Furthermore, we discuss the role of green and digital transformations in corporate finance. Thus, this research examines how enterprises improve their corporate financing environments through green transformation.

This study makes three significant contributions. First, it enriches empirical research on the microeconomic consequences of green transformation. Most existing literature discusses the economic effects of regional green transformation at the macro level [17–19] or analyzes the impact of external factors on corporate green transformation at the micro level [20–23]. However, few studies examine the effect of corporate green transformation on their development. Therefore, our research explores whether corporate green technology transformation can alleviate corporate financial constraints by providing micro-level empirical evidence that green transformation can optimize enterprises' financing environments and promote the development of the real economy.

Second, this study provides a feasible measure for transforming corporate green technology. Most existing literature only measures the overall level of corporate green transformation and does not deeply explore its structural aspects of corporate green transformation [23,24]. Based on reality, corporate green transformation includes substantive and strategic green transformation. Strategic green transformation means that enterprises package themselves as environmentally responsible or sustainable from various aspects such as green strategy, green operation, and green financing. However, the key to sustainable development is the substantive green transformation of energy saving and emission reduction that relies on green technology, not strategic green transformation. Therefore, we measure the level of substantive green transformation by constructing corporate green technology transformation indicators, which provide an essential reference for subsequent studies related to corporate green technology transformation. Specifically, we extract the feature words related to green transformation from the annual reports of listed companies and categorize these feature words into two categories: green technology transformation and green non-technology transformation. Finally, we employ the ratio of the total word frequency of green technology transformation to that of green transformation to measure corporate green technology transformation.

Third, this study has relevant policy implications for promoting green development and optimizing corporate financing environments. We show that green technology transformation can alleviate corporate financial constraints by increasing green subsidies and debt financing. The above results suggest that polluting enterprises should actively adopt green technologies to save energy and reduce emissions, which not only helps protect the environment but also helps enterprises obtain green subsidies and debt financing to eliminate their financial difficulties. In addition, we conclude that digital and green transformations have a synergistic effect on alleviating corporate financial constraints. Therefore, enterprises should promote the deep integration of digital technology and green transformation to optimize the corporate financing environment and promote high-quality development. Hence, our findings provide valuable policy references on how enterprises can achieve green transformation and optimize their financing environments.

The rest of this paper is organized as follows. Section 2 reviews the related literature. Section 3 provides the theoretical analysis and proposes our main hypotheses. Section 4 introduces data and methodology. Section 5 reports and discusses empirical results. Finally, Section 6 concludes our study and proposes policy recommendations.

2. Literature review

2.1. Green transformation of enterprises

With increasingly severe environmental problems and the introduction of environmental policies, the green transformation of enterprises has attracted considerable attention from all sectors of society. Green transformation not only helps solve environmental problems but also brings competitive advantages and long-term sustainable economic value to enterprises; therefore, an increasing number of enterprises are actively carrying out green transformation [22,25]. However, the theoretical connotations of corporate green transformation remain in the exploration stage. The green transformation of enterprises is defined as corporate behavior based on the concept of green development, oriented by green strategy, driven by green innovation, and obtaining environmental and economic benefits through green production [20]. Based on the transformation and upgrading theory, You and Yang (2022) point out that the green transformation of enterprises is the corporate green development that improves the utilization of resources and reduces pollution emissions [26]. Ding et al. (2023) argue that green transformation refers to enterprises achieving resource conservation and environmental protection through green technology and production [24].

Existing research on the green transformation of enterprises has mainly explored the key influencing factors and effective methods of green transformation. Most scholars believe that environmental regulations and financial policies are essential factors in promoting the green transformation of enterprises. Du and Li (2020) confirm that environmental regulations effectively reduce pollution emissions from industrial enterprises [3]. Su et al. (2023) conclude that greening of the tax system has a significant positive effect on the

green transformation of heavy enterprises [21]. Tian et al. (2022) find that the green credit policy introduced in China helps promote the green transformation of heavily polluting firms [27]. Wang et al. (2022) also point out that the issuance of green bonds by enterprises can improve their level of green technology and green innovation and guide them to embark on the path of sustainable development [28]. Companies can realize green transformation through green technological innovation [29,30], the introduction of external advanced production technology and pollution control technology [31,32], and a business model centered on the circular economy [33]. Overall, most existing research discusses the external factors driving the green transformation of enterprises but pays less attention to the impact of green transformation on companies' financing environment and long-term development.

2.2. Corporate financial constraints

Most literature on corporate financial constraints explores the implications of financial constraints and various factors affecting firms' operations. According to financial constraint theory, financial constraints refer to a situation in which, due to information asymmetry and transaction costs in incomplete capital markets, the cost of external financing for enterprises is higher than that of internal financing. This phenomenon leads enterprises to rely excessively on internal funds and invest below optimal levels [34]. Financial constraints are situations where firms face limitations or difficulties in obtaining external financing to meet their investments or operational needs [35]. On the one hand, the determinants of financial constraints include internal constraints related to the firm's characteristics, such as size, ownership structure, age, profitability, and reputation [36,37]. On the other hand, the influencing factors of financial constraints include external constraints determined by macroeconomic and market conditions, such as economic policy uncertainty, financial crisis, and laws [38–40].

2.3. Green transformation and financial development

Recently, an increasing number of studies have focused on the relationship between green transformation and financial development. At the macro level, numerous scholars believe that both green technological innovation and financial development have a significant impact on environmental protection [41,42]. Huang et al. (2023) find that green financial development significantly reduces carbon intensity by promoting green technological innovation, energy structure optimization, and industrial structure upgrading [43]. More specifically, Lv et al. (2021) point out that financial structure contributes to green technological innovation, while financial scale and financial efficiency have a negative impact on green technological innovation [44]. Han et al. (2022) believe that an improvement in financial agglomeration can promote green technology innovation [45].

At the micro level, many enterprises are gradually beginning green transformation and engaging in green finance; thus, green transformation may also affect corporate finance. Enterprises' contributions to environmental protection play a vital role in corporate social responsibility and positively impact corporate reputation and financial performance [46]. Additionally, Huang et al. (2023) explore the effects of corporate size, degree of internationalization, profits, and competitiveness on the degree of engagement in green finance and find that corporate size is positively related to the degree of engagement in green finance [47]. Huang et al. (2019) have demonstrated the positive role of green loans and government subsidies in promoting corporate green innovation [48]. Yao et al. (2021) show that external green credit policies can increase the financial constraints of polluting enterprises [49]. Wang et al. (2022) advocate that enterprises issuing green bonds may alleviate financial constraints [28]. An increasing number of scholars are focusing on the impact of green external financial policies on corporate financial constraints. However, few studies have analyzed how the green transformation of enterprises affects financial constraints based on corporate characteristics. In addition, enterprises can only obtain green policy support if they meet specific conditions. A question worth exploring is how enterprises can receive green policy support and thus improve their financial constraints. As corporate financial constraints play a crucial role in corporate investment decisions [50,51], innovation capacity [52], and market competitiveness [53,54], answering these questions is conducive to promoting corporate performance and sustainable economic development.

3. Theory and hypotheses

3.1. Proposal for green technology transformation

This study categorizes the green transformation of enterprises into green technology transformation and green non-technology transformation, according to whether enterprises rely on green technology for substantial transformation and upgrading. Green technology transformation entails the application of specific technologies, including new energy, energy saving, environmental protection, recycling, emissions, sewage treatment, low-carbon technology, and others [30,55,56]. Conversely, green non-technical transformation encompasses changes enterprises make in their green institutional framework, green cultural construction, green concept transformation, green strategic development, and other related aspects, including green image or environmental protection publicity [57–60]. Notably, the distinction between these two categories lies primarily in the fact that local governments' preferential subsidy policies often require enterprises to achieve a certain scale of green technology or projects. However, green financial instruments such as green credit and bonds are typically more stringent in approving green projects or green technologies implemented by enterprises owing to considerations of risk control and other factors [61–63]. To some extent, the different proportions of corporate investment in these two aspects reflect the quality difference in corporate green transformation. Enterprises with a higher proportion of green technology transformation are more willing to commit to substantive transformation and upgrading, while companies with a lower proportion of green technology transformation are more likely to adopt a "greenwashing" behavior [8,64].

3.2. Hypothesis development

Green technology transformation mainly affects corporate financial constraints through government subsidies and debt financing.

Government subsidy mechanism. The implementation of green subsidy policies has been found to effectively promote the green technology transformation of enterprises, stimulating their initiatives to increase green investment [65–67]. This trend has been observed in different provinces and cities across China, where governments have introduced various subsidy policies to support environmental protection, energy conservation, water conservation, and new energy. To be eligible for green subsidies, enterprises must meet specific indicators related to their infrastructure, management systems, energy resource inputs, products, environmental emissions, and performance. When the social and economic benefits derived from green subsidies exceed the costs of the corresponding green technology transformations undertaken by enterprises, these policies can induce increased investment, generating policy dividends [68,69]. Government subsidies help increase the sources of funds for enterprises [70], promoting the stable and sustained growth of corporate productivity while reducing corporate financial risks [36]. However, government subsidies also signal enterprises' green technology transformation to the market, which may further enhance the recognition of such transformations, thereby strengthening the overall signal effect of green technology transformation [71].

Debt financing mechanism. In the context of green finance policies, corporate green technology transformation may significantly impact different types of corporate debt financing. Corporate debt financing includes bank loans, corporate bonds, and commercial credit. Compared to other green financial instruments, green credit, and bonds are more widely used by enterprises; however, these instruments can significantly increase the debt financing scale [72,73]. Moreover, green technology transformation can enhance corporate reputation [46], which may affect business credit.

First, the green credit policy requires commercial banks to preferentially allocate credit resources to enterprises that implement green transformation and development and grants commercial banks a certain floating pricing authority. The green credit policy can directly increase the supply of bank loans in the financial market and enhance the debt-financing capacity of green technology transformation enterprises [74,75]. Green technology transformation can improve corporate information transparency and reduce the degree of information asymmetry. According to the pecking order theory, a company's financial constraints positively correlate with its degree of information asymmetry [76,77]. Thus, green technology transformation can increase credit resources and lower credit costs through green credit policies.

Second, enterprises that implement green technology transformation can issue green bonds related to green projects. Such endeavors may be deemed promising by investors who acknowledge the support of pertinent entities [78]. Due to their reduced credit risk, enterprises offering green bonds are prone to soliciting lower risk premiums. The extant literature posits that green bonds exhibit a discount relative to conventional bonds [12,13]. Therefore, the green transformation of enterprises can achieve more debt financing and lower financing costs by issuing green bonds [28,79,80].

Third, green technology transformation can increase business credit by enhancing corporate reputation. Specifically, the green technology transformation of enterprises is reflected in the production process, environmental protection foundation, environmental governance, and technological change, among others. This transformation can enhance the positive image of enterprises with respect to environmental protection, social responsibility, and governance, contributing to their environmental, social, and governance (ESG) performances. Enterprises with poor performance incur higher financing costs [81]. In addition, transaction vendors are more willing to provide business credit to reputable enterprises, improving their corporate debt financing.

Given the above analysis, we propose the following research hypothesis:

H1. Green technology transformation can alleviate corporate financial constraints.

4. Research design

4.1. Sample and data

Considering that China's accounting standards changed in 2007, the present analysis used a dataset of Chinese A-share listed firms observed between 2007 and 2022. We derived the corporate basic information and financial data from *China Stock Market Accounting Research* (*CSMAR*) and *Chinese Research Data Services* (*CNRDS*) databases. We also obtained annual report data from *Shanghai Stock Exchange*, *Shenzhen Stock Exchange*, and *cninfo.com*. We excluded firms in the financial industry, firms marked as "special treatment," or "particular transfer," or "delisted," and firms with many missing values during the sample period. We took the logarithm of total assets, total revenue, and company age. All continuous variables were winsorized at the 1% and 99% levels. Our final sample consisted of 30,665 firm-year observations over 16 years.

4.2. Model and variables

4.2.1. Model

We estimated the impact of green technology transformation on financial constraints using a fixed-effects model (Eq. (1)):

$$SA_{i,t} = \alpha + \beta GTT_{i,t} + \gamma X_{i,t} + \mu_i + \theta_t + \varepsilon_{i,t}, \tag{1}$$

where $SA_{i,t}$ refers to the financial constraint of firm i in year t. $GTT_{i,t}$ is the green technology transformation of firm i in year t. $X_{i,t}$ is a set of firm control variables. μ_i and θ_t are firm and year fixed effects, respectively. $\varepsilon_{i,t}$ are error terms. We cluster the standard errors by firm

to control for the firm-clustering effect.

4.2.2. Variables

Green Technology Transformation. Existing research provides valuable references for constructing a green technology transformation index. We connected firms' green transformation to specific green policies and then divided green transformation behavior into substantial transformational upgrades and strategic policy arbitrage. We further divided green transformation into green technology transformation and green non-technology transformation. This process makes it easier to analyze the structural differences in green transformation on firms' financial constraints. Corporate green transformation that conforms to national policy can be a signal to transmit a firm's green image to the market and is reflected in corporate annual reports. Therefore, it has significant value for interpreting non-standardized and non-structural textual information in annual reports.

The green technology transformation index was processed as follows. First, we used Python to obtain the annual reports of sample firms and converted them into files as a data pool for characteristic word extraction. Second, we analyzed the literature and policy documents and extracted characteristic words for a firm's green transformation. The sources of characteristic words were divided into three parts: (1) relevant literature with green transformation as the theme; (2) important policy documents, such as *Guidelines for Establishing the Green Financial System*, *Guidelines for Green Development of Outbound Investment and International Cooperation*, *Green Investment Guidelines (For Trial Implementation)*, *Industrial Green Development Plan (2016–2020)*, and (3) relevant technical guidance catalogs for green transformation.[1] We segmented the specific technical names in each technical guidance catalog and extracted common characteristic words that reflected a firm's green transformation. We then combined the characteristic words from the above three parts and obtained 118 characteristic words for green technology transformation and 71 for green non-technology transformation. Finally, using Python's word segmentation function, we searched for and matched keywords in the annual report to count each firm's total word frequencies of green technology transformation and green non-technology transformation each year. To weaken the impact of text length on the indicator, we used the ratio of green technology transformation frequency to the sum of the total frequency of green transformation to obtain the green technology transformation intensity index (GTT).

The keywords of green transformation and the mean values of GTT and green non-technology transformation are presented in Table A1 in the Appendix. Although the number of keywords for GTT (118 words) is larger than that for green non-technology transformation (71 words), the mean value of the total word count for GTT (14.11 words) of the sample firms is less than that for green non-technology transformation (25.59 words). This result indicates that the description of green technology applications in annual reports is weaker than that of the green technology concept.

Financial Constraints. Following existing research [35], we used the absolute value of *SA* index to measure firms' financial constraints, as shown in Eq. (2):

$$SA = \left| -0.737 \times Size + 0.043 \times Size^2 + 0.04 \times Age \right|, \tag{2}$$

where *Size* is the natural logarithm of the firm's total assets. *Age* refers to firm age. A higher *SA* suggests greater financial constraints.

Control Variables. Following previous research, we controlled for a set of firm characteristics to improve the estimation efficiency of the regression model: firm size (*lnAsset*), total income (*lnIncome*), leverage (*Lev*), return on assets (*Roa*), firm age (*Age*), Tobin's Q (*TobinQ*), revenue growth rate (*Growth*), and ownership of the largest shareholder (*Top1*). Table 1 provides the detailed definitions of all variables.

4.3. Descriptive statistics

Table 2 presents summary statistics for the main variables. The mean value of the *SA* index is 3.20, with a standard deviation of 0.10, indicating that listed companies in China generally face significant financial constraints. The mean value and median of GTT are 0.28 and 0.23, respectively, indicating that the average value of GTT of sample firms is relatively small. Firms report more descriptions of green non-technology transformation than green technology transformation in their annual reports. This result proves that companies generally package the image of green transformation but do not rely on green technologies for substantial transformation.

5. Results and discussion

5.1. Baseline regression results

Table 3 presents the baseline regression results. To present the impact of different types of green transformation on corporate

[1] *2005 Guidance Catalog for the Development of Renewable Energy Industry, 2010 National Key Catalog of Energy-Saving Technology (Third Batch), 2014 National Promotion Catalog of Low-Carbon Technology (First Batch), 2015 National Promotion Catalog of Low-Carbon Technology (Second Batch), 2015 Guidance Catalog of Advanced and Applicable Technology for Ecological Restoration of Water Saving and Sewage Treatment, 2016 National Catalog of Advanced Pollution Prevention and Control Technology (Field of VOCs Prevention and Control), 2016 National Encouraged Catalog of Environmental Protection Technology, 2017 National Key Catalog of Energy-Saving and Low-Carbon Technology (Low-Carbon Part), 2017 National Promotion Catalog of Low-Carbon Technology (Draft Standard for Comment), 2019 National Catalog of Advanced Pollution Prevention and Control Technology (Field of Water Pollution Prevention and Control), 2021 National Catalog of Advanced Pollution Prevention and Control Technologies (Field of Air Pollution Prevention and Control, Noise and Vibration Control)*.

Table 1
Variable definitions.

Category	Name	Variable	Definition
Dependent variables	Financial constraints	*SA*	$\lvert -0.737 \times Size + 0.043 \times Size^2 + 0.04 \times Age \rvert$
Independent variable	Green technology transformation	*GTT*	The word frequency of GTT/the total word frequency of green transformation
Control variables	Firm size	*lnAsset*	The natural logarithm of total assets
	Total income	*lnIncome*	The natural logarithm of total revenue
	Leverage	*Lev*	Liabilities/total assets
	Return on assets	*Roa*	Net profit/total assets
	Firm age	*Age*	The natural logarithm of firm age
	Tobin's Q	*TobinQ*	Market value/total assets
	Revenue growth Rate	*Growth*	(Revenues in year t - revenues in year t-1)/revenues in year t-1
	Ownership of the largest shareholder	*Top1*	Number of shares held by the largest shareholder/total number of shares

Table 2
Summary statistics.

Variables	Obs.	Mean	Std. Dev.	Min.	Median	Max.
SA	30665	3.2036	0.0954	2.5877	3.2333	3.2908
GTT	30665	0.2755	0.2463	0.0000	0.2329	1.0000
lnAsset	30665	8.2605	1.2169	5.3903	8.0734	12.3704
lnIncome	30665	7.5973	1.3682	4.7123	7.4503	11.8141
Lev	30665	0.3918	0.1948	0.0491	0.3835	0.8342
Roa	30665	0.0451	0.0551	−0.1796	0.0433	0.2163
Age	30665	2.8494	0.3590	1.6094	2.8904	3.5264
TobinQ	30665	1.9744	1.1276	0.8526	1.6091	7.1678
Growth	30665	0.0990	0.1535	−0.5963	0.0896	0.5617
Top1	30665	0.3448	0.1480	0.0873	0.3248	0.7510

Table 3
Baseline regression results.

Variables	(1)	(2)	(3)	(4)
	SA	SA	SA	SA
GTT	−0.0092***			
	(−2.5992)			
GT_ALL		−0.0051***		
		(−3.2294)		
GT1			−0.0096***	
			(−2.7292)	
GT2				−0.0065***
				(−2.9821)
lnAsset	−0.0082*	−0.0073	−0.0076	−0.0077*
	(−1.7711)	(−1.5753)	(−1.6285)	(−1.6552)
lnIncome	0.0018	0.0016	0.0015	0.0018
	(0.6063)	(0.5482)	(0.5272)	(0.6127)
Lev	0.0793***	0.0803***	0.0796***	0.0805***
	(9.3416)	(9.4837)	(9.4048)	(9.4832)
Roa	−0.0157	−0.0142	−0.0145	−0.0138
	(−0.6846)	(−0.6219)	(−0.6354)	(−0.6001)
Age	0.1309***	0.1297***	0.1297***	0.1302***
	(7.7389)	(7.6339)	(7.6307)	(7.6671)
TobinQ	−0.0006	−0.0005	−0.0006	−0.0005
	(−0.7547)	(−0.7425)	(−0.8027)	(−0.7196)
Growth	0.0118	0.0123	0.0123	0.0118
	(1.3858)	(1.4450)	(1.4441)	(1.3846)
Top1	−0.0768***	−0.0783***	−0.0764***	−0.0791***
	(−3.8898)	(−3.9706)	(−3.8658)	(−4.0083)
Constant	2.8842***	2.8836***	2.8841***	2.8832***
	(53.1035)	(52.9359)	(52.9462)	(52.9367)
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	30,665	30,665	30,665	30,665
Within-R^2	0.7143	0.7151	0.7148	0.7148

Note: ***, **, and * denotes significance at 1%, 5% and 10% levels, respectively, with t-values in parentheses.

financial constraints, we take the ratio of the total number of keywords related to all green transformations to the total number of words in the annual report (*GT_ALL*), the ratio of the number of keywords associated with GTT to the total number of words in the annual report (*GT1*), and the ratio of the number of keywords related to green non-technology transformation to the total number of words in the annual report (*GT2*) as independent variables in Columns (2) to (4).

In Column (1), the coefficient on *GTT* is significantly negative at the 1% level. This result indicates that GTT can relieve firms' financial constraints. The coefficient on *GT_ALL* in Column (2) is significantly negative at the 1% level, meaning that firms with higher levels of green transformation have fewer financial constraints. The coefficient on *GT1* in Column (3) is significantly negative at the 1% level and greater than that of *GT2* in Column (4). The results in Columns (3) and (4) show that the impact of green transformation on corporate financial constraints mainly stems from green technology transformation, consistent with the results in Column (1).

5.2. Endogeneity problems

We employ several methods to mitigate potential endogeneity problems in the model. First, considering that the initial conditions of enterprises with different levels of GTT may differ, the alleviation of corporate financing constraints through GTT may be the result of enterprises' independent choices, resulting in potential endogeneity problems. Hence, we set firms that have adopted green technology for more than seven consecutive years as the treatment group and the remaining firms as the control group and employ the propensity score matching (PSM) method to address the self-selection problem. We use the nearest neighbor PSM at a 1:1 ratio and set the treatment variable to one if GTT occurred, and zero otherwise. We use the logit model to estimate the effect and match the control group to the treatment group based on company characteristics, consistent with Eq. (1). We obtain a treatment group of 7140 observations and a control group of 7312 observations. After matching, the treatment and control groups have similar characteristics, enabling a comparative analysis. The results in Column (1) of Table 4 show that the coefficient on *GTT* is significantly negative at the 1% level after PSM. This result indicates that the alleviating effect of GTT on corporate financial constraints remains significant even after addressing the self-selection issue.

Second, the green transformation of firms is constrained not only by firm characteristics but also by the external environment. Therefore, we alleviate the endogeneity problems caused by potentially missing variables by controlling for regional factors and high-dimensional fixed effects. In Column (2) of Table 4, we control for price level (*CPI*), economic growth (*GDP*), and financial

Table 4
PSM method and controlling other factors.

Variables	(1) SA	(2) SA	(3) SA
	PSM	Controlling regional factors	High-dimensional fixed effects
GTT	−0.0109***	−0.0091**	−0.0082**
	(−2.7337)	(−2.5501)	(−2.1626)
lnAsset	−0.0026	−0.0084*	−0.0055
	(−0.4112)	(−1.8022)	(−1.2095)
lnIncome	−0.0003	0.0017	−0.0032
	(−0.0863)	(0.5971)	(−0.9827)
Lev	0.0701***	0.0803***	0.0781***
	(7.1960)	(9.5184)	(8.1412)
Roa	0.0299	−0.0160	0.0281
	(1.1298)	(−0.6986)	(1.1780)
Age	0.1285***	0.1304***	0.0945***
	(5.5054)	(7.7457)	(5.2777)
TobinQ	−0.0011	−0.0006	−0.0026***
	(−1.1970)	(−0.8015)	(−3.2074)
Growth	0.0032	0.0115	0.0047
	(0.3263)	(1.3552)	(0.5597)
Top1	−0.0869***	−0.0779***	−0.0572***
	(−3.5253)	(−3.9488)	(−2.7690)
CPI		0.0779	
		(0.8829)	
GDP		0.0252**	
		(2.2113)	
FD		0.0483**	
		(2.1710)	
Constant	2.8679***	2.0571***	2.9990***
	(40.4303)	(7.0152)	(50.9441)
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
City*Year FE	No	No	Yes
City*Industry FE	No	No	Yes
Industry*Year FE	No	No	Yes
Observations	14,452	30,665	30,665
Within-R^2	0.7265	0.7152	0.7484

Note: ***, **, and * denotes significance at 1%, 5% and 10% levels, respectively, with t-values in parentheses.

development (*FD*) at the regional level. The coefficient on *GTT* is significantly negative at the 5% level, and our main results still hold after considering regional factors. We also add high-dimensional fixed effects. Specifically, we add city*industry, city*year, and industry*year fixed effects to the other potential factors. Column (3) of Table 4 shows that the results are robust after controlling for as many multidimensional variables as possible.

Third, we adopt a one-period lag of explanatory and the instrumental variable methods to mitigate the endogeneity problem caused by reverse causation. Column (1) of Table 5 shows that the coefficient on *L.GTT* is significantly negative at the 5% level, supporting our findings. We also use the time of the firm's first green transformation as an instrumental variable to alleviate the endogeneity problem. Specifically, we obtain the start times of GTT and green non-technology transformation separately. Then, we calculate the difference between the sample year and these two times and take the natural logarithm of these two times to obtain *time1* and *time2*.

A higher *time1* suggests that the firm starts GTT earlier, and a higher *time2* indicates that the firm begins green non-technology transformation earlier. Finally, we use the ratio of *time1* to *time2* as the instrumental variable (*GTT_TIME*) for the estimation. *GTT_TIME* satisfies the exogeneity and relevance requirements of the instrumental variable. Regarding relevance, the earlier the firm starts the first green transformation, the higher the accumulated technological level and management experience, which helps proceed with the subsequent green transformations. Regarding exogeneity, the time of a firm's first green transformation is not directly related to its financial constraints except for its green transformation. The instrument's exogeneity requirement of the instrumental variable is largely satisfied after controlling for firm characteristics. The results in Column (2) of Table 5 show that the coefficient on *GTT_TIME* is significantly positive at the 1% level, and the results in Column (3) show that the coefficient on *GTT* in the second stage is significantly negative at the 1% level. The regression results for the instrumental variable confirm our previous findings.

5.3. Robustness checks

5.3.1. Alternative proxy of GTT

To ensure the robustness of our results, we further use the word frequency of GTT minus the word frequency of green non-technology transformation to measure the degree to which GTT exceeds green non-technology transformation (*GTT_A*). The higher *GTT_A* suggests a higher level of GTT and the lower *GTT_A* indicates a higher level of green non-technology transformation. Then we standardize by dividing the sum of the word frequency of GTT and green non-technology transformation (*GTT_EX*). We report the corresponding result in column (1) of Table 6. We find that the coefficient on *GTT_EX* remains negative and statistically significant, in line with our baseline results.

Table 5
One-period lag and IV method.

Variables	(1) SA	(2) GTT	(3) SA
	One-period lag of GTT	IV: First stage	IV: Second stage
L.GTT	−0.0080**		
	(−2.2377)		
GTT_TIME		0.0007***	
		(5.1657)	
GTT			−0.2270***
			(−4.0248)
lnAsset	−0.0150***	0.0232***	−0.0032
	(−3.1672)	(2.6919)	(−0.6653)
lnIncome	0.0019	−0.0101	−0.0005
	(0.6670)	(−1.3554)	(−0.1639)
Lev	0.0663***	−0.0228	0.0743***
	(7.8175)	(−1.0709)	(8.6734)
Roa	0.0073	0.0006	−0.0151
	(0.3201)	(0.0093)	(−0.6570)
Age	0.1293***	−0.0443	0.1202***
	(7.0634)	(−1.1920)	(7.0097)
TobinQ	−0.0043***	−0.0007	−0.0007
	(−5.4119)	(−0.3311)	(−0.9166)
Growth	0.0142*	0.0043	0.0129
	(1.6771)	(0.2000)	(1.5146)
Top1	−0.0780***	0.0452	−0.0669***
	(−3.8586)	(1.1928)	(−3.3508)
Constant	2.9560***	0.2803**	2.9482***
	(50.2791)	(2.4974)	(51.2311)
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	25,304	30,665	30,665
Within-R^2	0.7436	0.4880	0.7144

Note: ***, **, and * denotes significance at 1%, 5% and 10% levels, respectively, with t-values in parentheses. The results of instrumental variable test show that Anderson-Rubin Wald test F is 25.07 and Cragg-Donald Wald F is 53.903. Hence, our *GTT_TIME* is correlated with independent variable and we reject the null hypothesis that *GTT_TIME* is weak instrument.

5.3.2. Excluding municipalities

Municipalities enjoy greater autonomy and independence in administrative, political and economic aspects, while prefecture-level cities are more subject to the leadership and management of provincial governments. In order to exclude the influence of local government behavior patterns, we deleted the sample of municipalities for robustness test. The column (2) of Table 6 shows that the coefficient of *GTT* is significantly negative at the level of 1%, which is consistent with the baseline regression results.

5.3.3. Exclude non-industrial enterprise

In baseline regression, GTT covered industrial, commercial, real estate, public utilities, and other categories. Among these categories, industrial enterprises account for 75.83% of the total sample size of GTT, which is more than three-quarters of the total sample. Environmental pollution is largely caused by industrial production activities. Therefore, from the perspective of policy regulation and guidance, industrial enterprises receive more attention than other industries. The initiative of industrial enterprises to implement GTT is stronger than that of other industries. We further exclude non-industrial enterprises to eliminate the influence of sample self-selection. The result is reported in column (3) of Table 6. The coefficient of *GTT* is still significantly negative, which indicates that our results are also robust after excluding non-industrial enterprise samples.

5.4. Mechanism analysis

In the previous section, we have shown that promoting GTT can effectively alleviate enterprises' financial constraints. The causal relationship between GTT and financial constraints has been analyzed, but the mechanism has not been identified and tested. Based on the previous theoretical analysis, we further investigate the mechanism from the perspectives of government subsidies and debt financing, as shown in Eq. (3):

$$Sub_{i,t} \ / \ Loan_{i,t} \ / \ Bond_{i,t} / \ Credit_{i,t} = \alpha + \beta GTT_{i,t} + \gamma X_{i,t} + \mu_i + \theta_t + \omega_{i,t}, \tag{3}$$

where $Sub_{i,t}$ is the ratio of green subsidies to total subsidies for firm i in year t; $Loan_{i,t}$ refers to the bank loan obtained by firm i in year t; $Bond_{i,t}$ is the bond financing obtained by firm i in year t, and $Credit_{i,t}$ refers to the business credit obtained by firm i in year t. We obtain government subsidy data for enterprises from the *CSMAR* database and manually classify subsidies for different purposes. We select government subsidies closely related to green transformation and calculate the ratio of green subsidies to total subsidies (*Sub*). We use *Sub* as a proxy for green subsidies. According to theoretical analysis, enterprises with GTT mainly increase debt financing through bank loans and bond financing. Bank loans are measured as the ratio of bank loans to total assets (*Loan*), bond financing as the ratio of bond financing to total assets (*Bond*), and business credit as the ratio of business credit to total assets (*Credit*).

The results for the impact of government subsidies are shown in Column (1) of Table 7. The coefficient on *GTT* in Column (1) is

Table 6
Robustness checks.

Variables	(1) SA	(2) SA	(3) SA
	Alternative proxy of GTT	Excluding municipalities	Exclude non-industrial enterprise
GTT_EX	−0.0046***		
	(−2.5992)		
GTT		−0.0111***	−0.0081**
		(−2.6723)	(−2.0497)
lnAsset	−0.0082*	−0.0082	0.0006
	(−1.7711)	(−1.5590)	(0.1203)
lnIncome	0.0018	−0.0008	0.0002
	(0.6063)	(−0.2367)	(0.0510)
Lev	0.0793***	0.0853***	0.0805***
	(9.3416)	(8.7193)	(8.2806)
Roa	−0.0157	0.0084	0.0623**
	(−0.6846)	(0.3341)	(2.1893)
Age	0.1309***	0.1359***	0.1268***
	(7.7389)	(7.3289)	(6.9530)
TobinQ	−0.0006	−0.0014	−0.0005
	(−0.7547)	(−1.6287)	(−0.6405)
Growth	0.0118	0.0092	−0.0244**
	(1.3858)	(0.9257)	(−2.3807)
Top1	−0.0768***	−0.0846***	−0.0607***
	(−3.8898)	(−3.9659)	(−2.6406)
Constant	2.8796***	2.8922***	2.8330***
	(52.7736)	(47.4337)	(47.7345)
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	30,665	24,783	21,961
Within-R^2	0.7143	0.6632	0.7210

Note: ***, **, and * denotes significance at 1%, 5% and 10% levels, respectively, with t-values in parentheses.

significantly positive at the 5% level, indicating that the intensity of GTT can promote the proportion of green subsidies. These results also suggest that increasing green subsidies is an important mechanism for enterprises to alleviate financial constraints through GTT.

Columns (2) and (3) of Table 7 show the impact of debt financing. The coefficients on *GTT* in Columns (2) to (4) are significantly positive, indicating that GTT can help enterprises obtain bank loans, bond financing, and business credit, thereby increasing corporate debt financing. Therefore, debt financing is the main channel through which GTT alleviates financial constraints.

Overall, these results indicate that GTT can alleviate financial constraints by increasing green subsidies and promoting debt financing.

5.5. Cross-sectional tests

In this part, we conduct a series of cross-sectional tests to identify the heterogeneity of GTT in alleviating corporate financial constraints. More specifically, we are particularly interested in industry carbon intensity, political connections, and carbon emissions trading policy experiments.

5.5.1. The impact of industry carbon intensity

Carbon emission varies greatly due to differences in industry, and the carbon intensity attribute of the industry may also affect the implementation of corporate green transformation. Specifically, industries with higher carbon intensity are subject to higher environmental regulation, and green transformation may be more difficult for these industries. We select the top 13 industries based on the industrial carbon emissions released by *China Emission Accounts and Datasets* (*CEADs*) and *2012 edition of China Securities Regulatory Commission Industry Classification*, and define these industries as high-carbon-intensity, while other industries are defined as low carbon intensity. The regression results are shown in columns (1) to (2) of Table 8. The coefficient on *GTT* is significantly negative at the 5% level for both high and low carbon intensity industries. The difference in intergroup coefficients is statistically significant. The absolute value of the coefficient is larger in high-carbon-intensity industries, suggesting that the increase in GTT has a greater effect on alleviating corporate financial constraints in industries with higher carbon intensity.

5.5.2. The impact of political connections

Political connections may inhibit the level of corporate environmental governance, thereby affecting the alleviation of corporate financial constraints through green transformation. Rent-seeking theory suggests that government officials can use administrative power to intervene in corporate operations and provide government resources for companies with close relationships. Under the green performance evaluation system, local policies have a significant impact on corporate green transformation, and politically connected companies are more willing to spend money and energy to maintain political relationships to respond to the impact of policy instability. Therefore, we obtain executive data from *CSMAR* database, and select executives who are members of the National People's Congress and China People's Political Consultative Conference. Then, we divide our sample into high political connections and low

Table 7
Mechanism analysis.

Variables	(1)	(2)	(3)	(4)
	Sub	Loan	Bond	Credit
GTT	0.0001**	0.0041*	0.0029***	0.0014*
	(1.9855)	(1.7492)	(2.9638)	(1.9300)
lnAsset	−0.0001***	0.0369***	−0.0305***	−0.0272***
	(−2.7574)	(15.7721)	(−8.1693)	(−25.8642)
lnIncome	−0.0000	−0.0245***	0.0016	0.0259***
	(−0.9527)	(−12.1730)	(0.5432)	(25.9170)
Lev	−0.0001	0.4168***	0.1002***	0.1064***
	(−1.3205)	(68.4214)	(7.6535)	(37.0257)
Roa	0.0007***	−0.0893***	0.0527	0.0137
	(3.2331)	(−3.9153)	(1.3807)	(1.3217)
Age	−0.0001	0.0251***	−0.0251	−0.0164***
	(−1.2726)	(3.7825)	(−1.4977)	(−4.8759)
TobinQ	−0.0000	−0.0019***	−0.0062***	0.0003
	(−1.4400)	(−3.8480)	(−3.4340)	(1.1771)
Growth	−0.0003***	0.0175**	0.0049	−0.0184***
	(−4.2695)	(2.2085)	(0.3979)	(−5.3073)
Top1	0.0000	0.0149*	0.0433***	−0.0083*
	(0.2572)	(1.7333)	(3.0337)	(−1.8537)
Constant	0.0013***	−0.2486***	0.3343***	0.1283***
	(5.1181)	(−11.4021)	(5.8865)	(12.0159)
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	30,665	30,665	4156	30,665
Within-R^2	0.2946	0.7549	0.5573	0.8185

Note: ***, **, and * denotes significance at 1%, 5% and 10% levels, respectively, with t-values in parentheses.

Table 8
Heterogeneity analysis.

Variables	(1) SA	(2) SA	(3) SA	(4) SA	(5) SA	(6) SA
	High carbon-intensity industry	Low carbon-intensity industry	High political connection	Low political connection	Treatment group	Control group
GTT	−0.0167**	−0.0078**	0.0022	−0.0122***	−0.0171***	−0.0035
	(−2.0106)	(−2.0071)	(0.2621)	(−3.4119)	(−3.4914)	(−0.8743)
lnAsset	0.0089	−0.0114**	−0.0256**	−0.0038	0.0066	−0.0079
	(0.7924)	(−2.2436)	(−2.0626)	(−0.7703)	(0.9833)	(−1.4236)
lnIncome	0.0020	0.0021	0.0093	−0.0005	0.0022	−0.0021
	(0.2413)	(0.6889)	(1.4906)	(−0.1641)	(0.5848)	(−0.6427)
Lev	0.0522**	0.0833***	0.0829***	0.0750***	0.0506***	0.0827***
	(2.2495)	(9.0803)	(4.2095)	(7.8760)	(4.8233)	(7.5165)
Roa	−0.0857	−0.0044	−0.0553	−0.0044	0.0055	0.0087
	(−1.1819)	(−0.1866)	(−0.9066)	(−0.1854)	(0.2111)	(0.3015)
Age	0.1054**	0.1368***	0.1121**	0.1385***	0.1105***	0.1121***
	(2.5513)	(7.4243)	(2.3498)	(8.1401)	(4.6460)	(5.2163)
TobinQ	0.0030	−0.0013	−0.0003	−0.0003	−0.0049***	−0.0006
	(1.4959)	(−1.6280)	(−0.1807)	(−0.3862)	(−5.1606)	(−0.6001)
Growth	0.0405	0.0088	0.0250	0.0086	0.0063	0.0059
	(1.4157)	(1.0091)	(1.0348)	(1.0076)	(0.6838)	(0.5503)
Top1	−0.0774	−0.0768***	−0.0819**	−0.0676***	−0.0793**	−0.0614***
	(−1.5305)	(−3.5222)	(−2.3488)	(−2.8703)	(−2.5704)	(−2.5850)
Constant	2.8072***	2.8913***	3.0201***	2.8414***	2.8260***	2.9614***
	(20.8804)	(48.6848)	(19.8060)	(51.1447)	(34.5405)	(40.3684)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4591	26,074	6939	23,726	10,478	20,187
Within-R^2	0.7883	0.6963	0.7635	0.7337	0.8818	0.6794
Difference	0.009***		−0.014***		0.014***	
P-value	0.000		0.000		0.000	

Note: ***, **, and * denotes significance at 1%, 5% and 10% levels, respectively, with t-values in parentheses.

political connections according to their membership. The results are reported in column (3) and (4) of Table 8. We find that the coefficient of *GTT* is significantly negative in the subgroup with low political connections, but insignificant in the subsample with high political connections. The results indicate that political connections have an inhibiting effect on the motivation for GTT.

5.5.3. The impact of carbon emissions trading policy experiments

On October 2011, the National Development and Reform Commission issued the *Notification on Launching Pilot Work for Carbon Emissions Trading*, and approved Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, and Shenzhen to carry out carbon trading pilot work, which was officially launched in 2013. The start time of the carbon markets in Beijing, Shanghai, Shenzhen, Guangdong, and Tianjin was 2013, while the start time in Hubei and Chongqing was 2014, and the start time in Fujian was 2016.

Carbon emissions trading can internalize the externalities of excessive emissions. This incentive-based environmental regulation promotes corporate environmental investment, thereby positively promoting corporate green transformation. We divide our sample into the treatment group and the control group of carbon emissions trading policy experiments. Column (5) and (6) of Table 8 present the results. We find that the coefficient of *GTT* is significantly negative at the 1% level in the treatment group, but insignificant in the control group.

5.6. Digitization, green transformation and corporate financial constraints

The 14th Five-Year Plan for National Informatization proposes to deepen the construction of a green and smart ecological civilization, and promote the coordinated development of digitization and green transformation. On the one hand, digitization improves enterprise resource utilization and reduces carbon emissions through the comprehensive application of massive data. It also provides full-chain support for equipment connectivity and production efficiency in the green development of enterprises, empowering corporate green transformation. On the other hand, corporate green transformation is an important measure to achieve the carbon peaking and carbon neutrality goals, guiding the development direction of digitization.

The integration of digitization and green transformation mainly manifests in the networking of green low-carbon scenarios. The application of big data technology can help enterprises manage green data more efficiently, and the application of blockchain technology can change the channel of information transmission, providing security for the transmission of green data information. Under the exogenous impact of macro policies, the simultaneous digitization and green transformation of enterprises is an excellent quasi-natural experiment. Following the prior research, a net effect of the digitization and green transformation on financial constraints can be obtained by conducting two differences between the treatment group and the control group before and after transformation.

Considering the factors of firm and year fixed effects, we construct the following model (Eq. (4)) to analyze how digitization and green transformation affect corporate financial constraints:

$$SA_{i,t} = \alpha + \beta\left(du_i \times dt_{i,t}\right) + \gamma X_{i,t} + \mu_i + \theta_t + \varepsilon_{i,t}, \tag{4}$$

where du_i is a dummy variable. We use text analysis to count the word frequency of digitization in big data and blockchain, and set two different scenarios of GTT + big data and GTT + blockchain to examine the digitization and green transformation consequences brought about by digital technologies. $du_i = 1$ represents the group of enterprises that underwent digitization and green transformation during the sample period, and $du_i = 0$ represents the group that never underwent digitization and green transformation. Furthermore, we set a period dummy variable $dt_{i,t}$. When a firm undergoes digitization and green transformation for the first time, $dt_{i,t}$ takes the value of 1 for the current year and subsequent years, and 0 otherwise. β is the estimated parameter of key variable. In order to examine the digitization and green transformation effects of different digital technologies, samples that simultaneously use other digital technologies are excluded. Column (1) and (2) in Table 9 show the regression results. We find that the coefficients of green technology + big data technology (*GTT + Big Data*) and green technology + blockchain technology (*GTT + Blockchain*) are both significantly negative at the 1% level, indicating that digitization and green transformation have a synergistic effect and significantly mitigates enterprise financial constraints.

6. Conclusions and policy recommendations

6.1. Conclusions

The effective enhancement of green transformation quality and consequent improvement of enterprise resource acquisition capabilities are pivotal factors in promoting the development of the real economy. Using listed firms in China from 2007 to 2022 as a sample, this study investigates the impact of GTT on corporate financial constraints. The research findings indicate that improvements in GTT significantly alleviate corporate financial constraints. By executing GTT activities that encompass energy saving, emission reduction, environmental protection, and recycling, firms can enhance the proportion of green subsidies and expand the scale of debt financing, thereby alleviating financial constraints. The heterogeneity analysis shows that the impact of GTT on corporate financial constraints is more significant in high-carbon-intensity industries, firms with fewer political connections, and firms affected by the carbon trading pilot. Finally, we find a synergistic effect between digitization and green transformation that contributes to alleviating corporate financial constraints.

6.2. Policy implications

The conclusions of this study have the following implications for the green transformation of enterprises. First, from a policy-level standpoint, existing green policies have had a constructive impact on the influence of green transformation on corporate financial constraints. Therefore, to accomplish a comprehensive green transformation, a continuous refinement of policy measures and an expansion of policy coverage are imperative for the industry's benefit. Secondly, from the perspective of enterprises, the green transformation of enterprises focuses on action based on the long-term strategy of green development and supports substantive transformation and upgrading in the context of policy dividends. Finally, in light of the increasingly cutthroat global economic competition, digitization and greening have emerged as the two dominant trends in global economic and social transformations. Thus, it is essential to foster the deep integration of emerging technologies, such as the Internet and big data, with the green transformation of enterprises to promote long-term enterprise development.

6.3. Limitations and future research directions

Despite its contributions, this study has two limitations. First, we only examine the short-term impact of GTT on corporate financial constraints and do not discuss its long-term effects. Second, the GTT index in this study is measured using the green transformation characteristic words in the annual reports of China's listed firms. This index is an external reflection of enterprises' GTT and cannot comprehensively measure it. Therefore, future research should address these limitations in the following ways. First, it is recommended that the impact of GTT on corporate investment, innovation, corporate total factor, and other aspects be explored. Second, the long-term effects of green technological innovation on enterprise development should be investigated. Third, GTT should be measured using different dimensions to more comprehensively determine the degree of GTT in enterprises.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Jue Feng: Writing – original draft, Validation, Software, Methodology, Funding acquisition, Data curation. **Yingdong Wang:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization, Funding acquisition. **Wenzhi Xi:** Writing –

Table 9
Synergistic effect.

Variables	(1) SA	(2) SA
	GTT + Big Data	GTT + Blockchain
du × *dt*	−0.0157***	−0.0450***
	(−5.0015)	(−2.6723)
lnASSET	0.0063	−0.0002
	(1.0754)	(−0.0272)
lnIocome	0.0019	0.0023
	(0.5332)	(0.6122)
Lev	0.0514***	0.0632***
	(4.8971)	(5.8988)
ROA	0.0216	0.0257
	(0.7289)	(0.8771)
Age	0.1162***	0.1183***
	(5.1788)	(5.4703)
TobinQ	0.0025**	0.0015
	(2.5530)	(1.5223)
Growth	−0.0003	0.0017
	(−0.0271)	(0.1537)
Top1	−0.0495**	−0.0381*
	(−2.1547)	(−1.6549)
Constant	2.8462***	2.8117***
	(41.1427)	(37.5020)
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	14,911	13,154
Within-R^2	0.7156	0.7304

Note: ***, **, and * denotes significance at 1%, 5% and 10% levels, respectively, with t-values in parentheses.

review & editing, Writing – original draft, Validation, Project administration, Formal analysis.

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.

Acknowledgement

We would like to thank the editors and the reviewers for their valuable suggestions. This study was supported by the National Social Science Fund Key Project of China [Grant number: 22AGL008] and the 2020 Key Discipline Research Project of Yuncheng University [Grant number: XK-2020021].

Appendix

Table A1
Keywords of green transformation.

Category	Keywords
Green technology transformation	Achieving emission standards, emissions compliance, ultra-low emissions, reducing pollutant emissions, recycling and processing, centralized pollutant collection, solar energy, wind energy, nuclear energy, biomass energy, clean energy, clean and renewable energy, remediation and governance, environmental protection and remediation, soil ecological restoration, industrial flue gas treatment, urban environmental services, organic waste disposal, wind power generation, solar power generation and thermal utilization, biomass power generation, geothermal power generation, ocean energy power generation, hydropower generation, optimization technology, recycling technology, recycling and utilization, optimization systems, energy-saving systems, waste heat utilization, comprehensive utilization of waste heat, anti-scaling technology, energy-saving production, energy-saving technology, environmental protection technology, regeneration technology, collector technology, energy technology, distributed heating, heat utilization, scaled utilization, co-production technology, power generation technology, scaled collection, scaled application, remanufacturing technology, alternative fuel transformation, transformation technology, emission technology, decomposition technology, biomass charcoal, emission reduction technology, cluster control, gas substitution, secondary combustion, waste resource utilization, high-efficiency recycling, collaborative disposal, intelligent expansion, environmentally friendly, high-value utilization, recycling, resource utilization, energy storage applications, multi-

(*continued on next page*)

Table A1 (*continued*)

Category	Keywords
	co-production technology, construction waste regeneration production, recycling and utilization, water-saving and fertilization, energy-saving renovation, efficient heat exchange, energy-saving cluster control, integrated platform, intelligent heating, high-efficiency energy-saving, energy efficiency control, clean heating, zero energy consumption, treatment technology, purification technology, gas treatment, sewage reuse, incineration technology, ecological utilization, ecological restoration, wastewater technology, sewage treatment, comprehensive wastewater treatment, deep sewage treatment, reuse technology, waste heat recovery, dust removal technology, desulfurization technology, tail gas treatment, governance technology, resource utilization technology, harmless treatment, soil restoration, integrated treatment, noise control, comprehensive noise governance, emission detection, online monitoring, detection and warning, environmental risk assessment, recycled water, energy recovery, low energy consumption, emission reduction and pollution prevention, water purification, sewage hydrolysis, integrated sewage treatment, pollution reduction integration, deep treatment, integrated wastewater treatment technology, water quality goals, water quality protection, water quality assurance.
Green non-technology transformation	Green economy, green transformation, green projects, green products, green performance, green standards, green business, green industry, environmental facilities, sustainable production, sustainable development, low-carbon, green low-carbon, climate change, green management, green investment, fulfilling environmental responsibilities, environmental performance, environmental protection, environmental remediation, green regulation, green image, improving energy efficiency, reducing emissions, zero emissions, zero carbon, circular development, efficient use of resources, protecting the ecological environment, improving environmental information disclosure, effectively controlling carbon emissions, green investment, green construction, green production, green operations, green innovation, green concept, coordinated development, green procurement, environmentally friendly, green design, resource cycling, intensive, green brand, green infrastructure, green construction, comprehensive resource utilization, emission reduction management, environmental governance, ecological protection, compliance, negative carbon, carbon neutrality, pollution reduction and carbon reduction, ecological factory, circular utilization, circular economy, green environmental protection industry, energy conservation and environmental protection, renewable energy, resource recycling, green finance, green buildings, green credit, green bonds, green stocks, green development funds, green insurance, carbon finance, new energy, green coverage.

References

[1] X. Cai, Q. Liu, Q. Peng, International environmental regulation, trade liberalization, and enterprise pollution reduction: evidence from China, Front. Ecol. Evol. 10 (2022) 965484, https://doi.org/10.3389/fevo.2022.965484.

[2] L. Chen, F. He, Q. Zhang, W. Jiang, J. Wang, Two-stage efficiency evaluation of production and pollution control in Chinese iron and steel enterprises, J. Clean. Prod. 165 (2017) 611–620, https://doi.org/10.1016/j.jclepro.2017.07.155.

[3] W. Du, M. Li, Assessing the impact of environmental regulation on pollution abatement and collaborative emissions reduction: micro-evidence from Chinese industrial enterprises, Environ. Impact Assess. Rev. 82 (2020) 106382, https://doi.org/10.1016/j.eiar.2020.106382.

[4] W. Mao, W. Wang, H. Sun, Driving patterns of industrial green transformation: a multiple regions case learning from China, Sci. Total Environ. 697 (2019) 134134, https://doi.org/10.1016/j.scitotenv.2019.134134.

[5] J.Q. Wang, H.J. Cao, Improving competitive strategic decisions of Chinese coal companies toward green transformation: a hybrid multi-criteria decision-making model, Resour. Pol. 75 (2022) 102483, https://doi.org/10.1016/j.resourpol.2021.102483.

[6] W. Li, W. Li, V. Seppanen, T. Koivumaki, Effects of greenwashing on financial performance: moderation through local environmental regulation and media coverage, Bus. Strat. Environ. 32 (1) (2023) 820–841, https://doi.org/10.1002/bse.3177.

[7] M. Pizzetti, L. Gatti, P. Seele, Firms talk, suppliers walk: analyzing the locus of greenwashing in the blame game and introducing 'vicarious greenwashing', J. Bus. Ethics 170 (1) (2021) 21–38, https://doi.org/10.1007/s10551-019-04406-2.

[8] P. Seele, L. Gatti, Greenwashing revisited: in search of a typology and accusation-based definition incorporating legitimacy strategies, Bus. Strat. Environ. 26 (2) (2017) 239–252, https://doi.org/10.1002/bse.1912.

[9] X.K. Xu, J.S. Li, Asymmetric impacts of the policy and development of green credit on the debt financing cost and maturity of different types of enterprises in China, J. Clean. Prod. 264 (2020) 121574, https://doi.org/10.1016/j.jclepro.2020.121574.

[10] S.L. Chai, K. Zhang, W. Wei, W.Y. Ma, M.Z. Abedin, The impact of green credit policy on enterprises' financing behavior: evidence from Chinese heavily-polluting listed companies, J. Clean. Prod. 363 (2022) 132458, https://doi.org/10.1016/j.jclepro.2022.132458.

[11] R. Li, Y.W. Chen, The influence of a green credit policy on the transformation and upgrading of heavily polluting enterprises: a diversification perspective, Econ. Anal. Pol. 74 (2022) 539–552, https://doi.org/10.1016/j.eap.2022.03.009.

[12] J.Z. Wang, X. Chen, X.X. Li, J. Yu, R. Zhong, The market reaction to green bond issuance: evidence from China, Pac. Basin Finance J. 60 (2020) 101294, https://doi.org/10.1016/j.pacfin.2020.101294.

[13] O.D. Zerbib, The effect of pro-environmental preferences on bond prices: evidence from green bonds, J. Bank. Finance 98 (2019) 39–60, https://doi.org/10.1016/j.jbankfin.2018.10.012.

[14] Y.H. Chen, C. Wang, P.Y. Nie, Z.R. Chen, A clean innovation comparison between carbon tax and cap-and-trade system, Energy Strategy Rev. 29 (2020) 100483, https://doi.org/10.1016/j.esr.2020.100483.

[15] X. Huang, W. Liu, Z. Zhang, X. Zou, P. Li, Quantity or quality: environmental legislation and corporate green innovations, Ecol. Econ. 204 (2023) 107684, https://doi.org/10.1016/j.ecolecon.2022.107684.

[16] H.L. Ta, J.M. Liu, J. Mao, J.G. Wu, The effects of emission trading system on corporate innovation and productivity-empirical evidence from China's SO_2 emission trading system, Environ. Sci. Pollut. Res. 27 (17) (2020) 21604–21620, https://doi.org/10.1007/s11356-020-08566-x.

[17] S.Y. Hou, L.R. Song, J.Q. Wang, S. Ali, How land finance affects green economic growth in Chinese cities, Land 10 (8) (2021) 819, https://doi.org/10.3390/land10080819.

[18] X. Zhao, Y. Guo, T. Feng, Towards green recovery: natural resources utilization efficiency under the impact of environmental information disclosure, Resour, Policy 83 (2023) 103657, https://doi.org/10.1016/j.resourpol.2023.103657.

[19] F. Zhou, D. Si, P. Hai, P. Ma, S. Pratap, Spatial-temporal evolution and driving factors of regional green development: an empirical study in Yellow River Basin, Systems 11 (2) (2023) 109, https://doi.org/10.3390/systems11020109.

[20] W. Ge, Y. Xu, A. Razzaq, G. Liu, X. Su, X. Yang, Q. Ran, What drives the green transformation of enterprises? A case of carbon emissions trading pilot policy in China, Environ. Sci. Pollut. Res. 30 (19) (2023) 56743–56758, https://doi.org/10.1007/s11356-023-26283-z.

[21] Y. Su, X. Zhu, Y. Deng, M. Chen, Z. Piao, Does the greening of the tax system promote the green transformation of China's heavily polluting enterprises? Environ. Sci. Pollut. Res. 30 (19) (2023) 54927–54944, https://doi.org/10.1007/s11356-023-26027-z.

[22] X. Zhai, Y. An, Analyzing influencing factors of green transformation in China's manufacturing industry under environmental regulation: a structural equation model, J. Clean. Prod. 251 (2020) 119760, https://doi.org/10.1016/j.jclepro.2019.119760.
[23] C. Peng, X. Jia, Y. Zou, Does digitalization drive corporate green transformation? - based on evidence from Chinese listed companies, Front. Environ. Sci. 10 (2022) 963878, https://doi.org/10.3389/fenvs.2022.963878.
[24] X. Ding, Z. Xu, M.V.V. Petrovskaya, K. Wu, L. Ye, Y. Sun, V.M.M. Makarov, Exploring the impact mechanism of executives' environmental attention on corporate green transformation: evidence from the textual analysis of Chinese companies' management discussion and analysis, Environ. Sci. Pollut. Res. 30 (31) (2023) 76640–76659, https://doi.org/10.1007/s11356-023-27725-4.
[25] Y. Zhang, Z.Y. Sun, M.X. Sun, Y.Q. Zhou, The effective path of green transformation of heavily polluting enterprises promoted by green merger and acquisition-qualitative comparative analysis based on fuzzy sets, Environ. Sci. Pollut. Res. 29 (42) (2022) 63277–63293, https://doi.org/10.1007/s11356-022-20123-2.
[26] L. You, M. Yang, Transformation and upgrading path for midstream manufacturers in the chain: taking Shennan Circuits as an example, Front. Environ. Sci. 10 (2022) 1050976, https://doi.org/10.3389/fenvs.2022.1050976.
[27] C. Tian, X. Li, L. Xiao, B. Zhu, Exploring the impact of green credit policy on green transformation of heavy polluting industries, J. Clean. Prod. 335 (2022) 130257, https://doi.org/10.1016/j.jclepro.2021.130257.
[28] T. Wang, X. Liu, H. Wang, Green bonds, financing constraints, and green innovation, J. Clean. Prod. 381 (2022) 135134, https://doi.org/10.1016/j.jclepro.2022.135134.
[29] D. Li, M. Huang, S. Ren, X. Chen, L. Ning, Environmental legitimacy, green innovation, and corporate carbon disclosure: evidence from CDP China 100, J. Bus. Ethics 150 (4) (2018) 1089–1104, https://doi.org/10.1007/s10551-016-3187-6.
[30] Z.H. Li, Z.M. Huang, Y.Y. Su, New media environment, environmental regulation and corporate green technology innovation: evidence from China, Energy Econ. 119 (2023) 106545, https://doi.org/10.1016/j.eneco.2023.106545.
[31] L. Shi, H.X. Chen, H.L. Meng, R. Cheng, J.G. Dai, X. Zheng, Z.X. Zhang, How environmental policy impacts technology adoption: a case of landfill leachate, J. Clean. Prod. 310 (2021) 127484, https://doi.org/10.1016/j.jclepro.2021.127484.
[32] H.C. Cai, Z.L. Wang, Z.W. Zhang, L.Y. Xu, Does environmental regulation promote technology transfer? Evidence from a partially linear functional-coefficient panel model, Econ. Modell. 124 (2023) 106297, https://doi.org/10.1016/j.econmod.2023.106297.
[33] G. Cainelli, A. D'Amato, M. Mazzanti, Resource efficient eco-innovations for a circular economy: evidence from EU firms, Resour. Pol. 49 (1) (2020) 103827, https://doi.org/10.1016/j.respol.2019.103827.
[34] S.M. Fazzari, R.G. Hubbard, B.C. Petersen, Investment-Cash flow sensitivities are useful: a comment on Kaplan and Zingales, Q. J. Econ. 115 (2) (2000) 695–705, https://doi.org/10.1162/003355300554773.
[35] C.J. Hadlock, J.R. Pierce, New evidence on measuring financial constraints: moving beyond the KZ index, Rev. Financ. Stud. 23 (5) (2010) 1909–1940, https://doi.org/10.1093/rfs/hhq009.
[36] D. Czarnitzki, Research and development in small and medium-sized enterprises: the role of financial constraints and public funding, Scot. J. Polit. Econ. 53 (3) (2006) 335–357, https://doi.org/10.1111/j.1467-9485.2006.00383.x.
[37] C. Lin, Y. Ma, Y.H. Xuan, Ownership structure and financial constraints: evidence from a structural estimation, J. Financ. Econ. 102 (2) (2011) 416–431, https://doi.org/10.1016/j.jfineco.2011.06.001.
[38] M. Campello, J.R. Graham, C.R. Harvey, The real effects of financial constraints: evidence from a financial crisis, J. Financ. Econ. 97 (3) (2010) 470–487, https://doi.org/10.1016/j.jfineco.2010.02.009.
[39] H. Ma, D. Hao, Economic policy uncertainty, financial development, and financial constraints: evidence from China, Int. Rev. Econ. Finance 79 (2022) 368–386, https://doi.org/10.1016/j.iref.2022.02.027.
[40] H. Wang, X. Xiang, L. Han, Financial development, legal systems and SME finance: cross-country evidence, Int. Rev. Econ. Finance 88 (2023) 981–1002, https://doi.org/10.1016/j.iref.2023.07.021.
[41] U. Habiba, C. Xinbang, A. Anwar, Do green technology innovations, financial development, and renewable energy use help to curb carbon emissions? Renew. Energy 193 (2022) 1082–1093, https://doi.org/10.1016/j.renene.2022.05.084.
[42] Y.J. Wang, J.B. Huang, Pathway to develop a low-carbon economy through energy-substitution technology in China, Energy 261 (2022) 124964, https://doi.org/10.1016/j.energy.2022.124964.
[43] J.B. Huang, L.F. An, W.H. Peng, L.L. Guo, Identifying the role of green financial development played in carbon intensity: evidence from China, J. Clean. Prod. 408 (2023) 136943, https://doi.org/10.1016/j.jclepro.2023.136943.
[44] C.C. Lv, C.H. Shao, C.C. Lee, Green technology innovation and financial development: do environmental regulation and innovation output matter? Energy Econ. 98 (2021) 105237 https://doi.org/10.1016/j.eneco.2021.105237.
[45] Z.X. Han, X.Y. Li, Z. Yan, K.Y. Zhong, Interaction and spatial effects of green technology innovation and financial agglomeration: empirical evidence from China under the goal of "double carbon", Front. Environ. Sci. 10 (2022) 984815 https://doi.org/10.3389/fenvs.2022.984815.
[46] Z. Jing, G.S. Hossain, S. Rahman Badiuzzaman, N. Hasan, Does corporate reputation play a mediating role in the association between manufacturing companies' corporate social responsibility (CSR) and financial performance? Green Financ 5 (2) (2023) 240–264, https://doi.org/10.3934/gf.2023010.
[47] Y.C. Huang, K.D. Yu, C. Huang, Green finance engagement: an empirical study of listed companies on Chinese main board, Green Financ 5 (1) (2023) 1–17, https://doi.org/10.3934/gf.2023001.
[48] Z.H. Huang, G.K. Liao, Z.H. Li, Loaning scale and government subsidy for promoting green innovation, Technol. Forecast. Soc. 144 (2019) 148–156, https://doi.org/10.1016/j.techfore.2019.04.023.
[49] S. Yao, Y. Pan, A. Sensoy, G.S. Uddin, F. Cheng, Green credit policy and firm performance: what we learn from China, Energy Econ. 101 (2021), https://doi.org/10.1016/j.eneco.2021.105415.
[50] H. Almeida, M. Campello, Financial constraints, asset tangibility, and corporate investment, Rev. Financ. Stud. 20 (5) (2007) 1429–1460, https://doi.org/10.1093/rfs/hhm019.
[51] S. Chava, M.R. Roberts, How does financing impact investment? The role of debt covenants, J. Finance 63 (5) (2008) 2085–2121, https://doi.org/10.1111/j.1540-6261.2008.01391.x.
[52] Y. Gorodnichenko, M. Schnitzer, Financial constraints and innovation: why poor countries don't catch up, J. Eur. Econ. Assoc. 11 (5) (2013) 1115–1152, https://doi.org/10.1111/jeea.12033.
[53] J. Du, N. Bach, Cognitive financial constraints and firm growth, Small Bus. Econ. 58 (4) (2022) 2109–2137, https://doi.org/10.1007/s11187-021-00503-7.
[54] C. Wang, S. Zhao, H. Zheng, Y. Bai, Does financial constraint hinder firm growth? Emerg. Mark. Finance Trade 58 (15) (2022) 4195–4206, https://doi.org/10.1080/1540496x.2022.2069490.
[55] S.R. Paramati, M. Di, R.X. Huang, The role of financial deepening and green technology on carbon emissions: evidence from major OECD economies, Finance Res. Lett. 41 (2021) 101794, https://doi.org/10.1016/j.frl.2020.101794.
[56] Q.H. Wang, J.S. Qu, B. Wang, P.L. Wang, T.B. Yang, Green technology innovation development in China in 1990-2015, Sci. Total Environ. 696 (2019) 134008, https://doi.org/10.1016/j.scitotenv.2019.134008.
[57] I.J. Ismail, D. Amani, I.A. Changalima, Strategic green marketing orientation and environmental sustainability in sub-Saharan Africa: does green absorptive capacity moderate? Evidence from Tanzania, Heliyon 9 (7) (2023) e18373, https://doi.org/10.1016/j.heliyon.2023.e18373.
[58] Y.H. Ling, Examining green policy and sustainable development from the perspective of differentiation and strategic alignment, Bus. Strat. Environ. 28 (6) (2019) 1096–1106, https://doi.org/10.1002/bse.2304.
[59] K.K. Papadas, G.J. Avlonitis, M. Carrigan, L. Piha, The interplay of strategic and internal green marketing orientation on competitive advantage, J. Bus. Res. 104 (2019) 632–643, https://doi.org/10.1016/j.jbusres.2018.07.009.
[60] G.H. Yang, B.L. Liu, Research on the impact of managers' green environmental awareness and strategic intelligence on corporate green product innovation strategic performance, Ann. Oper. Res. 326 (2023) 5, https://doi.org/10.1007/s10479-021-04243-5, 5.

[61] R. Chen, The effects of green credit policy on the formation of zombie firms: evidence from Chinese listed firms, Environ. Sci. Pollut. Res. 29 (53) (2022) 80669–80682, https://doi.org/10.1007/s11356-022-21033-z.
[62] Y. Ge, Y. Zhu, Boosting green recovery: green credit policy in heavily polluted industries and stock price crash risk, Resour. Pol. 79 (2022), https://doi.org/10.1016/j.resourpol.2022.103058.
[63] B.H. Peng, W.M. Yan, E. Elahi, A.X. Wan, Does the green credit policy affect the scale of corporate debt financing? Evidence from listed companies in heavy pollution industries in China, Environ. Sci. Pollut. Res. 29 (1) (2022) 755–767, https://doi.org/10.1007/s11356-021-15587-7.
[64] L. Gatti, M. Pizzetti, P. Seele, Green lies and their effect on intention to invest, J. Bus. Res. 127 (2021) 228–240, https://doi.org/10.1016/j.jbusres.2021.01.028.
[65] M.T. Benkhodja, V. Fromentin, X. Ma, Macroeconomic effects of green subsidies, J. Clean. Prod. 410 (2023) 137166, https://doi.org/10.1016/j.jclepro.2023.137166.
[66] Y. Li, Y. Tong, F. Ye, J. Song, The choice of the government green subsidy scheme: innovation subsidy vs. product subsidy, Int. J. Prod. Res. 58 (16) (2020) 4932–4946, https://doi.org/10.1080/00207543.2020.1730466.
[67] Z. Li, Y. Pan, W. Yang, J. Ma, M. Zhou, Effects of government subsidies on green technology investment and green marketing coordination of supply chain under the cap-and-trade mechanism, Energy Econ. 101 (2021) 105426, https://doi.org/10.1016/j.eneco.2021.105426.
[68] Y. Shao, Z. Chen, Can government subsidies promote the green technology innovation transformation? Evidence from Chinese listed companies, Econ. Anal. Pol. 74 (2022) 716–727, https://doi.org/10.1016/j.eap.2022.03.020.
[69] Y. Yi, Y. Wang, C. Fu, Y. Li, Taxes or subsidies to promote investment in green technologies for a supply chain considering consumer preferences for green products, Comput. Ind. Eng. 171 (2022) 108371, https://doi.org/10.1016/j.cie.2022.108371.
[70] J. Hinloopen, More on subsidizing cooperative and noncooperative R&D in duopoly with spillovers, J. Econ. 72 (3) (2000) 295–308, https://doi.org/10.1007/BF01231269.
[71] T. Yann, J. Pinkse, Opportunistic behaviors in green signaling: when do firms engage in symbolic green product preannouncement? Int. J. Prod. Econ. 218 (2019) 287–296, https://doi.org/10.1016/j.ijpe.2019.06.015.
[72] C. Lv, J. Fan, C.-C. Lee, Can green credit policies improve corporate green production efficiency? J. Clean. Prod. 397 (2023) 136573 https://doi.org/10.1016/j.jclepro.2023.136573.
[73] H. Wen, C.-C. Lee, F. Zhou, Green credit policy, credit allocation efficiency and upgrade of energy-intensive enterprises, Energy Econ. 94 (2021) 105099, https://doi.org/10.1016/j.eneco.2021.105099.
[74] S. Chai, K. Zhang, W. Wei, W. Ma, M.Z. Abedin, The impact of green credit policy on enterprises' financing behavior: evidence from Chinese heavily-polluting listed companies, J. Clean. Prod. 363 (2022) 132458, https://doi.org/10.1016/j.jclepro.2022.132458.
[75] B. Xi, Y. Wang, M. Yang, Green credit, green reputation, and corporate financial performance: evidence from China, Environ. Sci. Pollut. Res. 29 (2) (2022) 2401–2419, https://doi.org/10.1007/s11356-021-15646-z.
[76] A. De Jong, M. Verbeek, P. Verwijmeren, Firms' debt-equity decisions when the static tradeoff theory and the pecking order theory disagree, J. Bank. Finance 35 (5) (2011) 1303–1314, https://doi.org/10.1016/j.jbankfin.2010.10.006.
[77] M.T. Leary, M.R. Roberts, The pecking order, debt capacity, and information asymmetry, J. Financ. Econ. 95 (3) (2010) 332–355, https://doi.org/10.1016/j.jfineco.2009.10.009.
[78] D. Azhgaliyeva, Z. Kapsalyamova, Policy support in promoting green bonds in Asia: empirical evidence, Clim. Pol. 23 (4) (2023) 430–445, https://doi.org/10.1080/14693062.2023.2167800.
[79] E. Agliardi, R. Agliardi, Financing environmentally-sustainable projects with green bonds, Environ. Dev. Econ. 24 (6) (2019) 608–623, https://doi.org/10.1017/s1355770x19000020.
[80] I. Sangiorgi, L. Schopohl, Explaining green bond issuance using survey evidence: beyond the greenium, Br. Account. Rev. 55 (1) (2023) 101071, https://doi.org/10.1016/j.bar.2021.101071.
[81] A. Goss, G.S. Roberts, The impact of corporate social responsibility on the cost of bank loans, J. Bank. Finance 35 (7) (2011) 1794–1810, https://doi.org/10.1016/j.jbankfin.2010.12.002.