Green Finance

Green Finance, 8(2): 236–270.
DOI: 10.3934/GF.2026009
Received: 04 November 2025
Revised: 01 March 2026
Accepted: 13 March 2026
Published: 17 April 2026

https://doi.org/www.aimspress.com/journal/GF

Research article

Impact of local governments' green attention on firm green transformation in China: Empirical evidence based on the BERTopic method

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Abstract: Local governments play an important role in promoting firms' green transformation through policy guidance, financial support, regulatory measures, and resource allocation. In this study, we used A-share listed companies on the Shanghai and Shenzhen Stock Exchanges from 2010 to 2023 as research samples and explored the relationship and underlying mechanisms between local governments' green attention (GGA) and firm green transformation (FGT) using textual analysis techniques. The empirical results showed that higher GGA significantly promotes FGT. Mechanism analysis indicates that GGA enhances FGT by strengthening firms' green innovation capacity and improving environmental information disclosure. In addition, firms' greenwashing prevention measures further strengthen the positive effect of GGA on FGT. The relationship between GGA and FGT varies across ownership types, pollution intensity, and levels of GGA. This study enriches the theoretical and practical understanding of government attention in promoting firm green transformation and provides insights for guiding local government behavior and improving corporate green governance.

Keywords: firm green transformation; local governments' green attention; green innovation; environmental information disclosure; greenwashing behavior; textual analysis

JEL Codes: D22, G18, G38, Q01

1. Introduction

Local governments' green attention (GGA) has become an important driving force in promoting environmental protection and green development. As environmental challenges intensify, particularly climate change, resource scarcity, and ecological degradation, local governments have assumed increasingly prominent responsibilities in protecting the ecological environment and advancing sustainable development. They exert significant influence over green standards, industrial policies, resource allocation, and benefit distribution. Environmental regulations, green policies, economic incentives, and public environmental attention at the local government level directly affect firms' green transformation (FGT) decisions. However, firms face numerous challenges in the green transformation process, including high transformation costs, technological barriers, limited access to professional expertise, and uncertainty in market demand. Consequently, FGT requires firms to continuously conduct self-assessment and improvement, formulate green strategic plans, and strengthen green governance capabilities to achieve long-term coordination among environmental, economic, and social benefits. By actively responding to climate change, reducing environmental impacts, and improving resource-use efficiency throughout production and operation processes, firms can achieve sustainable development and long-term competitive advantages. Therefore, our primary objective of this study is to explore the influence mechanisms between GGA and FGT, focusing on how GGA promotes FGT through green innovation, the suppression of greenwashing behavior, and improved environmental information disclosure.

Studies indicate that government decision-making and environmental regulation significantly affect green transformation. Government environmental attention promotes regional green transformation by increasing environmental governance expenditure and improving public environmental services (Man et al., 2024). Digital government transformation enhances regional green innovation and green total factor energy efficiency through green financial development, green talent agglomeration, and the mitigation of resource curse effects (Bie et al., 2024; Wang et al., 2024; Yang et al., 2024). Government environmental attention also boosts green total factor productivity by fostering green technological innovation and optimizing resource allocation (Zhao et al., 2022; Du et al., 2024; Zhang et al., 2024d). Moreover, it improves green efficiency and air quality, thereby promoting regional green development (Bao and Liu, 2022; Sun et al., 2023; Dong and Xu, 2024; Tu et al., 2024).

GGA serves as a policy signal, a tool for guiding public opinion, and a means of shaping a supportive atmosphere for green transformation. As a non-mandatory or semi-mandatory soft policy instrument, GGA exerts a significant influence on FGT performance. Government environmental attention can reduce firms' carbon emissions through environmental regulations, fiscal expenditure, and subsidy policies (Liu et al., 2023a, 2023b; Meng et al., 2024), and positively affect green investment by expanding green credit supply and strengthening local environmental regulations (Chen et al., 2024). In contrast, carbon taxation may negatively affect firms' green investment decisions (Wei et al., 2020). Government and public environmental attention significantly influence firms' green innovation performance (Akhtar et al., 2024; Fang and Liu, 2024; Xu et al., 2024). The GGA level reshapes firms' long-term green development strategies by signaling policy priorities related to green transformation in government work reports. These signals enhance potential benefits and value creation while stimulating firms' intrinsic motivation for green development. They include sustainable development planning, green technology catalogs, the selection of model green enterprises, green credit guidelines, and environmental protection initiatives, all of which influence firms' green transformation performance.

Environmental regulation represents an external regulatory pressure that compels firms to adopt end-of-pipe treatments and other green transformation measures. As a compulsory and universal policy tool, environmental regulation has a significant impact on FGT. It promotes industrial green transformation by reducing carbon emission intensity, encouraging technological innovation, and shaping government behavior (Zhai and An, 2020). Environmental regulation also facilitates urban green transformation through green technological innovation and industrial structure upgrading (Du et al., 2022; Liu and Chen, 2022; Sun and Zhou, 2024). However, some studies revealed an inverted U-shaped relationship between environmental regulation and environmental governance efficiency in China's steel and iron industries (Li et al., 2019; Zhu et al., 2021; Wang et al., 2023). As a hard policy instrument, environmental regulation enforces compliance by establishing explicit standards, such as pollutant emission limits, carbon emission quotas, and environmental approval procedures. Firms that violate these regulations face stricter administrative supervision and legal or administrative penalties, including fines, production suspensions, or license revocations.

Local governments also implement green incentive policies, such as green finance, green taxation, and environmental governance measures, to reduce the costs of FGT and enhance the benefits of green practices. These policies aim to achieve a win-win outcome for corporate profitability and societal green objectives. Government subsidies improve firms' green technological innovation and the adoption of emerging green technologies by strengthening technological integration and innovation input capacity (Shao and Chen, 2022; Feng and Xue, 2023; Duan et al., 2024; Tawiah and Zakari, 2024). Government guidance funds and subsidies significantly enhance FGT performance (Li and Wu, 2024; Sun et al., 2025). Green finance policies promote FGT by providing financial support (Lu et al., 2022; Zhang et al., 2024a), while green credit policies have a significant positive effect on FGT (Li and Chen, 2022; Tian et al., 2022; Lin and Pan, 2024; Tan et al., 2025). In addition, green finance and sustainable development policies advance regional green transformation through energy structure optimization and technological innovation (Wang et al., 2022; Zhang et al., 2024c). Low-carbon policies promote green transformation among high-carbon -emitting firms (Su et al., 2024), and environmental laws and green governance policies enhance firms' carbon risk awareness, thereby increasing FGT (Long et al., 2022; Deng et al., 2024). Conversely, environmental policy uncertainty suppresses firms' green innovation and total factor productivity (Zhou et al., 2024). Environmental tax policies positively influence green mergers and acquisitions among highly polluting firms (Hu et al., 2023), while carbon trading policies promote firm sustainability by improving green finance, green investment, and green innovation (Wang et al., 2025). Overall, effective green policies align corporate self-interest with policy objectives by optimizing the cost–benefit structure of sustainability efforts. For example, carbon trading schemes enable firms to reduce emission abatement costs, enhance profitability through improved energy efficiency, and generate revenue by selling surplus emission allowances. Subsidies and tax incentives further link corporate interests with societal benefits, enabling firms to access additional fiscal resources through green transformation.

Government work reports (GWRs) represent the top-level policy design and public commitments of local governments for the year ahead and are released at the beginning of each year. As authoritative official policy documents, GWRs encapsulate social consensus and play a decisive guiding role in local government actions. They reflect policy priorities and resource allocation intentions, embodying governments' strategic concerns during specific periods. Here, we measure GGA across seven policy dimensions: carbon peaking, carbon neutrality, energy saving and emission reduction, environmental governance, sustainable development, green fiscal and financial policies, and green technology applications. The GGA level captures clear signals regarding future resource allocation, policy formulation, and evaluation orientations. It reflects a proactive policy stance with strong foresight, helping to mitigate reverse causality concerns. As a leading indicator derived from policy texts, GGA provides a continuous, quantifiable, and comparable measure that addresses lag and endogeneity issues associated with traditional indicators such as environmental governance investment or pollutant compliance rates. Higher GGA levels are closely linked to subsequent policy implementation, interdepartmental coordination, local performance assessments, and resource prioritization, signaling credible policy commitments. Through these mechanisms, GGA promotes firms' green transformation by enhancing public interests, expanding green credit availability, fostering corporate green innovation, and improving environmental governance and energy-saving capabilities.

There is a close interactive relationship between GGA and FGT. Higher levels of GGA can significantly enhance FGT through policy guidance, financial support, and market incentives. Environmental regulations and standards formulated by local governments encourage firms to upgrade sustainable technologies and strengthen green management capabilities, thereby promoting green transformation. Through funding subsidies and technical support, local governments reduce the economic burden of FGT and encourage firms to increase investment in environmental protection. As a result, improvements are achieved in resource utilization, pollution reduction, environmental impact, production efficiency, and sustainable development capacity. Studies show that government decision making, environmental regulation, and green policies significantly influence FGT. However, few researchers have examined the relationship and impact mechanisms between GGA and FGT. From the perspective of government attention behavior, this study extends the GGA FGT nexus and makes three major contributions.

First, we measure GGA and FGT using the BERTopic model and corporate greenwashing behavior using the Word2Vec model. We expand 221 green transformation keywords across seven dimensions, including energy saving and emission reduction, environmental governance, green finance, sustainable development, carbon peaking, carbon neutrality, and green technology, thereby extending previous keyword systems. Figures 2 and 3 construct a theoretical measurement framework for GGA and FGT based on the BERTopic approach. Moreover, we qualitatively measure GGA and FGT using BERTopic and quantitatively evaluate FGT through eight measurable indicators, extending measurement methods. Compared with prior greenwashing studies, we enrich the measurement of corporate greenwashing by scientifically defining selective disclosure and expressive manipulation using the Word2Vec model.

Second, we empirically examine the linkage between GGA and FGT and address research gaps related to government behavior and green transformation. The results show that higher GGA significantly enhances current and future FGT performance, as demonstrated in Tables 4, 5, and 6. Research confirms that government environmental attention promotes green investment, green innovation, and carbon governance. This study further reveals that the promotion effects vary by ownership structure, pollution intensity, and GGA level. Higher GGA exerts stronger effects on nonstate owned and heavily polluting firms than on state owned and nonpolluting firms, and stronger effects under high GGA conditions than under low GGA conditions.

Third, this study enriches the theoretical and empirical mechanisms linking GGA and FGT, as shown in Figure 1 and Table 7. We identify positive channels through corporate environmental information disclosure and green innovation, as well as a negative channel through the reduction of corporate greenwashing behavior. While studies show that government environmental attention improves corporate social responsibility, ESG performance, and green innovation, this study further clarifies the influence mechanisms of GGA on FGT by incorporating disclosure quality and greenwashing mitigation from a government behavior perspective.

The remainder of this article is organized as follows: In Section 2, we introduce related concepts, theoretical analysis, and research hypotheses. In Section 3, we describe the data sources, variable definitions, and research design. In Section 4, we present the baseline results, robustness tests, mechanism analysis, and heterogeneity analysis. In Section 5, we conclude with the major findings and policy implications.

2. Theoretical mechanism and research hypothesis

2.1. Related concepts

The Government Work Reports (GWR), as official documents, often reflect the level of attention policymakers give to issues (Bao and Liu, 2022). Government environmental attention refers to how local officials prioritize environmental issues and allocate resources in decision-making, highlighting the crucial role of local governments in advancing environmental mandates (Chen et al., 2024; Du et al., 2024).

GGA refers to the prioritization of specific issues or major topics, such as sustainable development and dual-carbon governance, in policymaking. It emphasizes the pivotal role of government in forming and implementing green policies. In this study, local governments focus on issues, including energy saving and emission reduction, environmental governance, green finance, sustainable development, carbon peaking, carbon neutrality, and the application of green technologies. By strengthening the implementation of these policies, GGA stimulates the enthusiasm for FGT. GGA not only affects the priority of green policies but also influences the allocation of resources and their effectiveness.

FGT reflects sustainable development activities in green technology progress, green production processes, green products, and environmental management quality (Scoones et al., 2015; Cheba et al., 2022). FGT describes how firms actively or passively reduce resource consumption, minimize environmental pollution, and improve environmental performance through green technology innovation, sustainable strategy management, and green governance practices, thereby achieving sustainable development targets (Tan et al., 2025; Wang et al., 2024). FGT involves multiple aspects, including production processes, product design, supply chain management, and market strategies, emphasizing the overall improvement of firms' green governance performance. Key components of FGT include green technology research and development, green product promotion, green management implementation, energy conservation and emission reduction, and environmental governance. FGT relies on business activities that enhance resource utilization efficiency and reduce environmental impacts, such as green technology innovation, green management innovation, clean production technology, circular economy models, efficient resource usage, and renewable energy adoption.

This green transformation not only enhances firms' economic performance but also emphasizes social responsibility and ecological benefits, aiming to establish a sustainable development model that balances environmental and economic objectives.

2.2. Theoretical analysis and research hypothesis

The promotion effect of GGA on FGT operates through three interrelated mechanisms.

First, GGA strengthens policy signals and incentive mechanisms. Higher government attention to ecological protection and green development promotes the formulation and implementation of green policies, including green finance, subsidies, tax incentives, and market access regulations. These policies provide clear policy direction and market expectations for firms to engage in green transformation related to resource utilization, pollution control, and technological innovation, thereby reducing uncertainty in green investment decisions (Chen et al., 2024a; Liu et al., 2024b). Attention theory suggests that stronger GGA improves the effectiveness and execution of green policy instruments, enhancing corporate environmental governance and accelerating FGT performance. Resource allocation theory further indicates that higher GGA encourages firms to increase financial and resource investment, creates green market opportunities, improves resource allocation efficiency, and enhances long term market benefits (Du et al., 2024). The stability and continuity of GGA also strengthen firms' market confidence, support long-term green strategies, and enhance brand value and social image, thereby encouraging further green transformation activities.

Second, GGA increases regulatory intensity and compliance pressure. Higher levels of GGA are often associated with stricter environmental regulations, such as unified emission standards, ecological restoration requirements, and pollution penalties. These measures strengthen environmental supervision, raise firms' awareness of environmental responsibility, and increase the cost of pollution and noncompliance (Bao and Liu, 2022; Liu et al., 2023a; Chen et al., 2024). Under stricter regulation, firms are more likely to adopt measures to reduce resource consumption and emissions, improve environmental governance efficiency, and reduce uncertainty in green transformation decisions. External institutional pressure can also create green market opportunities, enhance environmental performance, and promote long-term sustainable development strategies. Increased compliance pressure incentivizes firms to improve resource efficiency, strengthen public trust, gain government support, and promote FGT (Liu et al., 2023a; Tu et al., 2024).

Third, GGA amplifies public supervision and social benefits. Rising public attention and environmental expectations encourage firms to improve environmental behavior and actively pursue green transformation to meet market demand and social expectations (Xu et al., 2024; Zhang et al., 2024b). Stakeholder theory suggests that firms enhance social responsibility, corporate reputation, and brand value through improved environmental performance, thereby generating green premiums. Pressure from the public and stakeholders motivates firms to adopt cleaner energy sources, cleaner production methods, and stronger green governance practices, further accelerating FGT.

Based on the above analysis, we propose the following hypothesis:

Hypothesis 1**:** Higher levels of government green attention promote firm green transformation.

Firm green transformation requires continuous improvement in internal green governance capabilities, ranging from frontend environmental information disclosure, to mid stage green technology innovation, and to the prevention of greenwashing behavior. Environmental information disclosure reflects firms' transparency and environmental performance, including disclosures related to environmental investment, greenhouse gas and pollutant emissions, environmental protection measures, and the outcomes of green governance practices.

First, government work reports serve as an effective channel for information dissemination. GGA communicates clear signals about government support, resource allocation, economic incentives, and green governance actions. Higher GGA usually leads to stricter requirements for environmental information disclosure and enables firms to access more fiscal subsidies, tax rebates, and policy resources. These supports reduce the costs of green governance, enhance economic and environmental returns, and improve FGT performance.

Second, higher GGA strengthens environmental regulation and legislative pressure. Legitimacy theory suggests that increased GGA raises regulatory expectations, encouraging firms to disclose environmental governance practices more transparently. Signal transmission theory indicates that stronger policy pressure creates a stronger deterrent effect. Environmental violations damage corporate reputation and may result in financial penalties, which can negatively affect green investment decisions. Improved environmental disclosure enhances corporate credibility, builds trust with investors and regulators, and indirectly promotes firm green transformation.

Third, higher GGA attracts greater public and media attention, which increases external supervision and strengthens executives' environmental awareness. Attention theory shows that executives allocate more focus to environmental governance when policy signals are strong. This improves firms' environmental responsibility, resource allocation, energy conservation, and emission reduction efforts. Increased transparency also helps firms coordinate internal and external resources, strengthen green governance practices, and improve FGT performance.

Hypothesis 2: GGA has a significant positive impact on FGT by promoting environmental information disclosure.

Firm green innovation refers to the development and application of environmentally friendly technologies, products, and services that reduce environmental impacts and enhance sustainable development capacity.

First, higher GGA intensifies environmental regulation and institutional pressure. Stronger environmental laws and standards increase compliance costs, encouraging firms to improve green technologies. According to Porter's hypothesis, innovation gains can offset compliance costs and create an innovation compensation effect.

Second, stakeholder theory suggests that higher GGA strengthens government firm relationships and expands access to policy support, fiscal subsidies, tax incentives, and priority resources. These incentives reduce investment risks and motivate firms to increase green research and development, thereby enhancing environmental efficiency and competitive advantage.

Third, higher GGA increases green development pressure while improving firms' resource reserves, which boosts green innovation efficiency. Under external pressure, firms often adopt technological and managerial innovation to reduce costs and expand market opportunities. Green innovation improves clean energy use, emission reduction, and environmental governance, directly enhancing FGT performance and supporting sustainable development goals.

Hypothesis 3: GGA accelerates firm green transformation by promoting green innovation activities.

Green washing refers to firms presenting misleading or exaggerated environmental claims without corresponding actions. This behavior harms corporate credibility and weakens the effectiveness of green policies.

First, stricter GGA increases regulatory pressure and compliance costs, such as investments in environmental equipment and monitoring. Firms engaging in green washing face stronger market punishment, consumer resistance, and loss of competitiveness, which reduces innovation capacity and slows FGT performance. Higher GGA increases the risks and costs of green washing, discouraging such behavior.

Second, green washing sends false signals to obtain policy benefits and social recognition. Signal theory suggests that stricter GGA reduces information asymmetry and helps identify misleading environmental claims through stronger regulation and disclosure (Chen et al., 2024c). Stakeholder theory indicates that credible green performance attracts financial support and reduces risk, while green washing undermines investor confidence and weakens FGT efficiency.

Third, higher GGA improves communication of green governance policies and increases public and investor scrutiny. Stronger supervision reduces suspicion, improves investor confidence, and enhances firms' motivation for genuine green transformation, thereby suppressing green washing behavior.

Hypothesis 4: GGA promotes firm green transformation by suppressing greenwashing behavior.

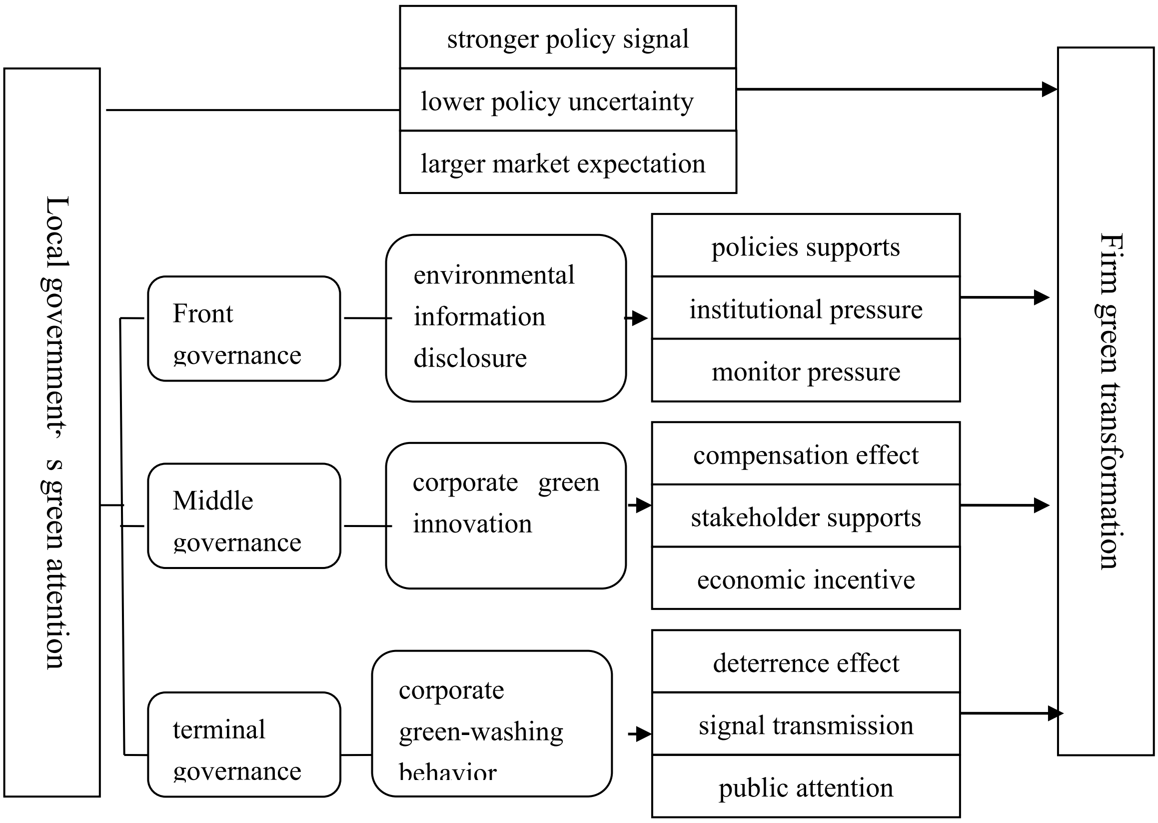

Figure 1. The influence mechanism between GGA and FGT.

3. Research design

3.1. Sample selection and data source

FGT is measured as the total frequency of all keywords related to green transformation in the management discussion and analysis (MD&A) sections of annual financial reports, using a green transformation dictionary. The annual financial reports of firms are obtained from the Shanghai and Shenzhen Stock Exchange platforms through web crawling methods. GGA is measured as the total frequency of green transformation keywords in government work report (GWR) texts for 290 prefecture-level cities, excluding Xizang, Hong Kong, Macao, and Taiwan. All urban GWR texts are collected from official government websites and the Peking University Treasure database.

The sample consists of A-share listed companies from the Shanghai and Shenzhen Stock Exchanges. Firms with special treatment status (ST and ST*), financial institutions, and observations with missing data are excluded, resulting in 30,049 observations. The panel data cover the period 2010 to 2023. For heterogeneity analysis, heavily polluting industries are identified based on the 2012 revised "Industry Classification Guidelines for Listed Companies" issued by the China Securities Regulatory Commission. The industry codes for these sectors are listed in Table 1.

Other financial data are obtained from the China Stock Market & Accounting Research Database and RESSET Database. For fundamental regression, robustness checks, mechanism tests, and heterogeneity analysis, all empirical results are winsorized at 1% on both tails to reduce the impact of extreme values.

Table 1. Classification and Codes of Heavily Polluting Industries in China.

Industry Code	Industry Name	Industry Code	Industry Name
B06	Coal mining and washing industry	B07	Oil and gas extraction industry
B08	Ferrous metal mining and beneficiation industry	B09	Non-ferrous metal mining and beneficiation industry
C17	Textile industry	C19	Leather, fur, feather and related products industry
C22	Paper and paper products industry	C25	Petroleum processing, coking, and nuclear fuel processing industry
C26	Chemical raw material and chemical product manufacturing industry	C28	Chemical fiber manufacturing industry
C29	Rubber and plastic products industry	C30	Non-metallic mineral products industry
C31	Ferrous metal smelting and rolling processing industry	C32	Non-ferrous metal smelting and rolling processing industry
D44	Electricity and heat production and supply industry		

3.2. Variable selection and measurement

3.2.1. Firm green transformation

The textual information of green transformation in MD&A sections reflects firms' resource inputs, market potential, technological progress, and future strategies. The BERTopic model is used to extract topics, combining BERT pre-trained language models with dimensionality reduction (UMAP) and density-based clustering (HDBSCAN). The main workflow for measuring FGT is illustrated in Figure 2.

Step 1: Construct a green transformation dictionary.

Seven dimensions of green transformation policies are obtained from the Peking University Law Treasure website via web crawlers. Texts are segmented using the Jieba tool to create a specialized green transformation corpus. Following Chang et al. (2024) and Tan et al. (2025), keywords with frequency greater than 10 are selected, resulting in 221 keywords. These cover carbon peak (38 keywords), carbon neutrality (54 keywords), green fiscal and finance (35 keywords), energy saving and emission reduction (28 keywords), ecological environment governance (40 keywords), sustainable development (44 keywords), and green technology application (30 keywords). Keywords include energy structure optimization, carbon conversion, decarbonization technology, hydrogen energy, energy storage technology, and others.

Step 2: Obtain firms' MD&A texts.

Annual financial reports of A-share listed companies from 2010 to 2023 are collected from the Shanghai and Shenzhen Stock Exchanges and CNINFO website. A Python web crawler is developed to automatically download PDF files and convert them into text format.

Step 3: Preprocess firms' MD&A texts.

The green transformation dictionary is integrated into the Jieba segmentation library to ensure accurate recognition of professional terms. Each green transformation keyword is assigned a high frequency weight (set at 1000) to prioritize extraction. A stop-word dictionary from Harbin Institute of Technology is used to remove function words, particles, and other non-essential items. Numbers, English letters, and special symbols are eliminated using regular expressions, retaining only Chinese characters.

Step 4: Feature vector extraction.

The "Paraphrase-Multilingual-MiniLM- L12-v2" model from the Sentence-Transformers framework is used to extract feature vectors from the MD&A texts. This model performs well in cross-linguistic tasks. A Bag-of-Words (BOW) transformer is configured with a maximum text length of 3000 and a word vector dimension of 1024, balancing computational efficiency with feature coverage. This ensures accurate extraction of contextual semantic features for FGT measurement.

Step 5: Theme Modeling.

During model training, we employ BERTopic and use a Sentence Transformer encoder to convert preprocessed MD&A texts into high-dimensional vectors representing their overall semantic features. Nonlinear dimensionality reduction is performed using Uniform Manifold Approximation and Projection (UMAP), reducing the text vectors to a dimension of 10. After dimensionality reduction, Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN) is applied. Through multiple iterations and parameter optimization, HDBSCAN automatically identifies the optimal number of clusters, uncovering potential feature topics in the MD&A texts and enhancing the representational capacity of topic modeling. Each theme is represented by a set of keywords related to green transformation, and the model calculates the probability distribution of each document across all themes.

Step 6: Identification of Green Transformation Themes.

To enhance interpretability, each identified theme is mapped to a list of keywords extracted from the MD&A texts. The similarity between these keywords and the green transformation dictionary is calculated using the formula:

$$\text{Similarity}=\frac{\left|\left\{K \middle| K \in K_t \cap K_g\right\}\right|}{\left|K_t\right|} \tag{1}$$

Here, K_t denotes the set of keywords representing green theme t, and K_g represents the vocabulary set in the green transformation dictionary. We establish a threshold of 0.1, meaning that if at least 10% of the keywords in the green theme, K_t is found in the green transformation dictionary, then the corresponding green theme will be classified as related to green transformation.

Step 7: FGT Measurement.

FGT is measured based on the probability distribution of green transformation themes within each document. For each document *d*, the FGT indicator is calculated as the sum of probabilities across all green transformation-related themes:

$$G_g = \sum_{t \in T_g} P_d(\mathrm{t}) \tag{2}$$

Here, G_g denotes the degree of green transformation for document d, T_g is the set of all green transformation-related themes, and $P_d(t)$ represents the probability that document d belongs to theme t.

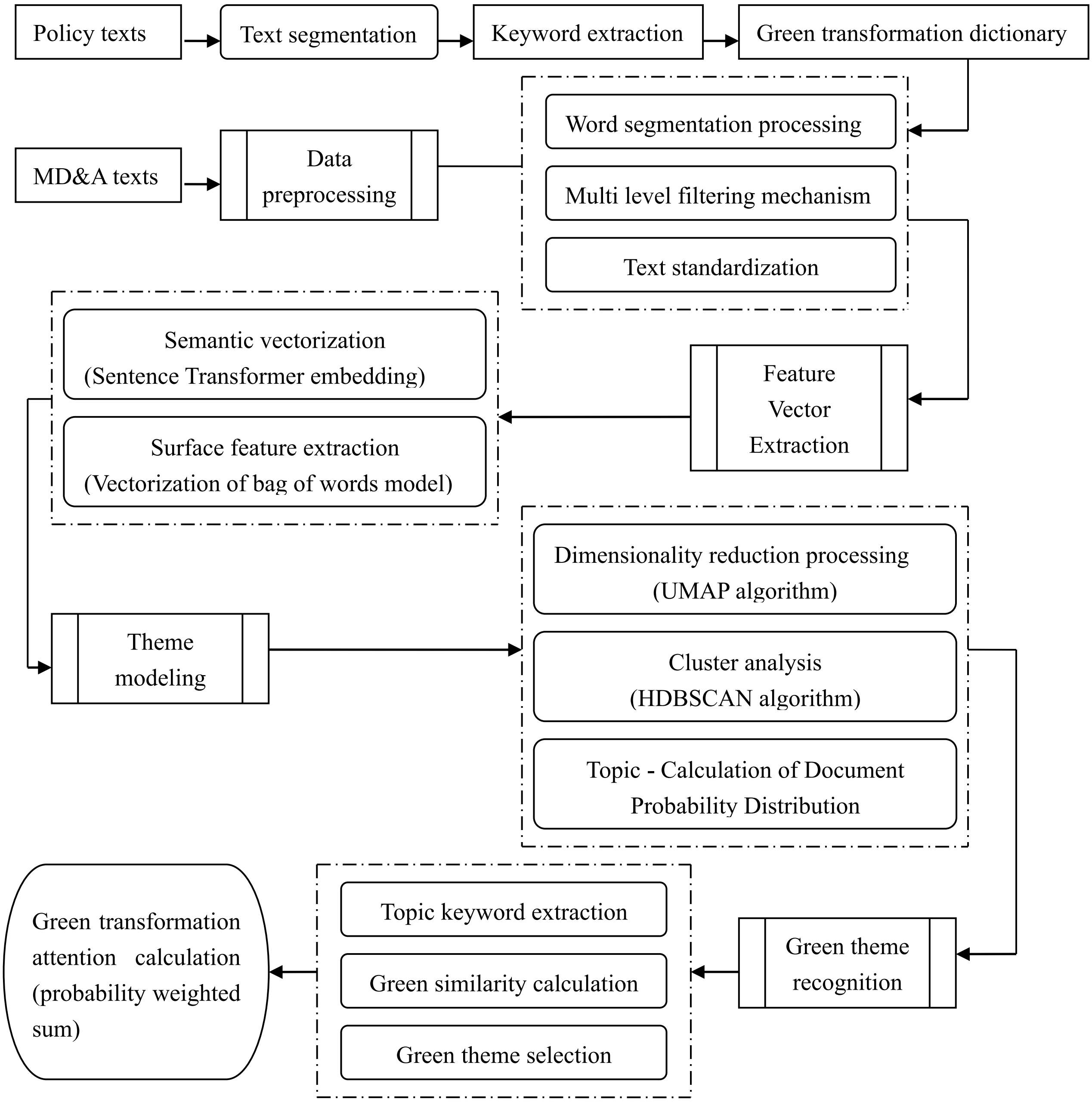

Figure 2. Measuring FGT using the BERTopic model.

3.2.2. Local governments' green attention

Textual information analysis is widely used to measure local government attention (Bao and Liu, 2022; Du et al., 2024; Liu et al., 2023a, 2023b). This approach quantifies attention by calculating the proportion of cumulative frequencies of words related to specific topics or priority issues relative to the total vocabulary in urban government work report (GWR) texts. Urban GWR texts serve as the "baton" of local government attention, reflecting policy priorities, resource allocation efficiency, and changes in policy instruments. In this study, based on the seven dimensions of green transformation keywords, the urban GGA level reflects local governments' prioritization of green transformation policies and resource allocation for dual-carbon targets, energy conservation, emissions reduction, environmental governance, sustainable development, green finance, fiscal policy, and green technology applications. The cumulative word frequency of green transformation keywords in GWR texts provides a systematic and intuitive indicator of government green attention. The measurement process involves five major steps:

Step 1: Urban GWR Text Collection.

Web crawler technology is used to collect government work reports from 290 Chinese cities between 2010 and 2023 via official municipal websites and the Peking University Law-Treasure database. Reports in PDF format are converted to TXT files.

Step 2: Urban GWR Text Preprocessing.

The "Jieba" segmentation tool is used to process the GWR texts, integrating a green transformation vocabulary into the corpus to ensure accurate recognition of specialized terms. Mis-segmentation of specific terminology is avoided. Additionally, the Harbin Institute of Technology stop-word dictionary is applied to remove common function words, auxiliary words, and high-frequency low-information terms.

Step 3: Construction of a Green Theme Vector.

The BERTopic model is trained in four stages. First, the multilingual MiniLM embedding model (paraphrase-multilingual-MiniLM-L12-v2) converts GWR texts into high-dimensional vectors. UMAP reduces the vectors to five dimensions while preserving local and global structures. HDBSCAN clustering is applied with CountVectorizer parameters fine-tuned (min_df and max_df) to balance keyword specificity and coverage. Representative keywords from each cluster are extracted, forming feature vectors that capture green themes from the GWR texts.

Step 4: Green Theme Recognition.

Using the green transformation dictionary, overlap between green theme keywords and dictionary terms is calculated. A threshold rule is applied: If the overlap exceeds the set threshold, the theme is classified as a green attention theme. Set operations are used to refine green themes and ensure accurate identification.

Step 5: GGA **Intensity Measurement.**

The cumulative word frequency of identified green attention keywords is multiplied by 100 and divided by the total word count of the GWR text. This proportion quantifies the green content in the GWR and reflects the degree of local government green attention.

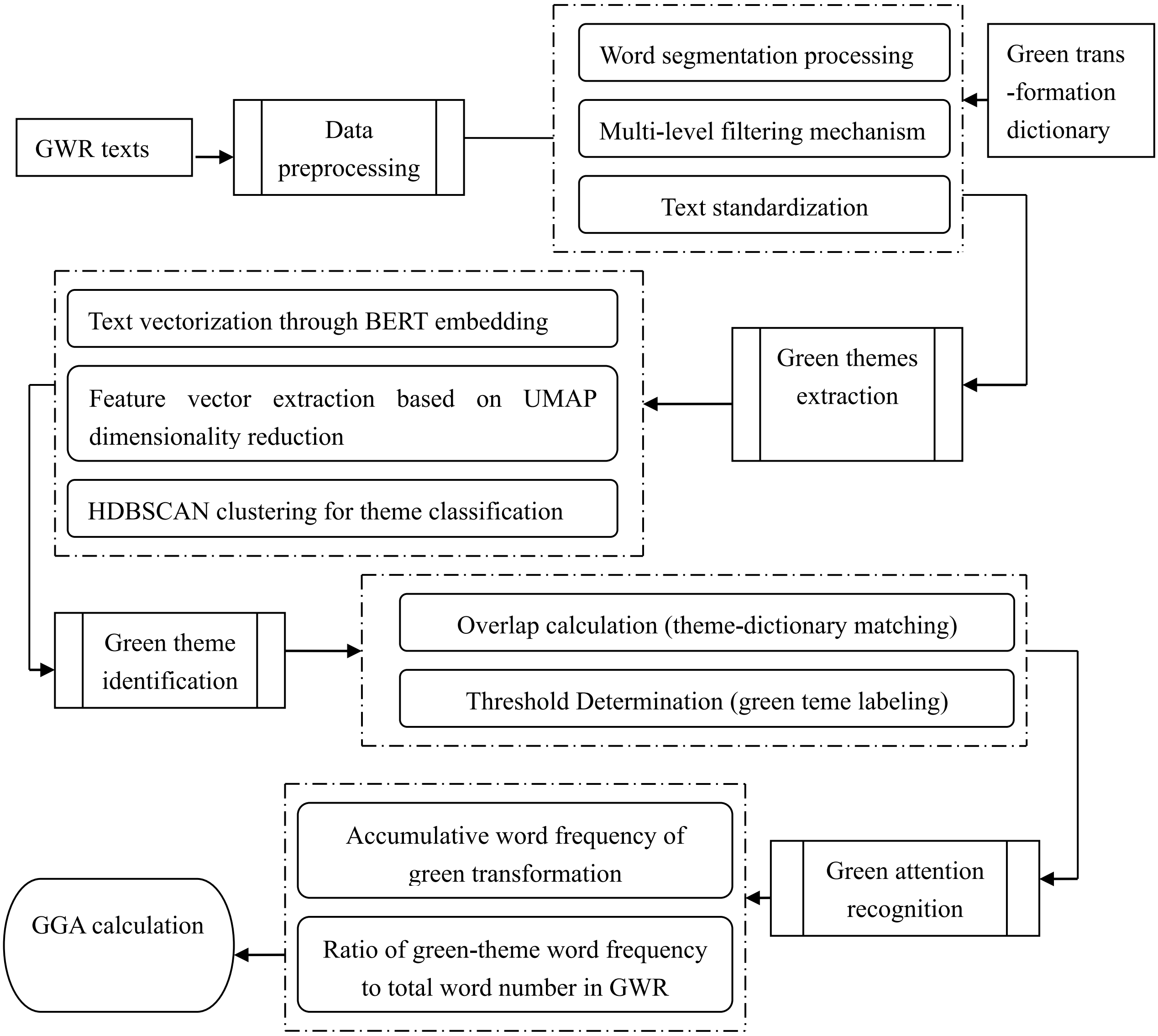

Figure 3. Technical Flowchart of GGA Measurement Based on the BERTopic Model.

3.2.3. Influence mechanism variables

According to the evaluation report on environmental responsibility information disclosure of listed companies in China (Ministry of Environmental Protection, 2015), the content evaluation method is used to measure firm environmental information disclosure. Disclosure is divided into five parts: disclosure carrier (3 secondary indicators), environmental management (8 secondary indicators), environmental supervision and certification (2 secondary indicators), environmental liabilities (6 secondary indicators), and environmental performance and governance (6 secondary indicators). Scoring rules are as follows: Descriptive information is scored as 1 for disclosure and 0 for non-disclosure; non-disclosed numerical information is 0, qualitative disclosure is 1, and quantitative disclosure is 2. The cumulative actual score is divided by the maximum score of 25 to measure firm environmental information disclosure (Cheng and Feng, 2023; Chen et al., 2024b).

Firms' green innovation is primarily measured by the number of green patent applications. Counting these patents quantifies firms' investment and achievements in green technology research and development. The number of green patent applications provides a reliable and accurate indicator of a firm's green innovation capacity. The green patent data come from the State Intellectual Property Office and conform to international standards published by WIPO, ensuring authority and reliability. These patents cover not only physical production equipment and machines but also technological and process innovations, reflecting firms' green innovation achievements and resource utilization efficiency. Compared with other indicators, the number of green patents more effectively measures firms' green innovation capacity. Firm green innovation is defined as the natural logarithm of the number of applied green patents plus 1 (Du et al., 2022; Akhtar et al., 2024; Chen et al., 2024a).

Firm green-washing (FGW) behaviors are defined as the difference between the standardized ESG disclosure score and the ESG performance score (Tao et al., 2024; Zhang, 2024). In this study, we measure corporate green-washing behavior using selective disclosure (hard information) and expressive manipulation (soft information) with the Word2Vec method (Hong et al., 2023; Gomes et al., 2024; Li et al., 2024a, 2024b). The measurement involves five steps:

First, defining selective disclosure and expressive manipulation.

Green-related keywords from eight dimensions of green transformation are used to define selective disclosure and expressive manipulation. Selective disclosure refers to hard indicators that are specific, objective, quantifiable, and verifiable, such as environmental investment, energy conservation, emission reduction, green technologies, and third-party audits. Expressive manipulation is soft information, often vague statements that are difficult to verify, such as commitments to environmental protection or future green initiatives.

Second, preprocessing MD&A texts.

All MD&A texts are segmented using the Jieba tool, with punctuation, numbers, and stop words removed to obtain clean text.

Third, expanding Word Vectors for green-washing.

Word2Vec is used to train word vectors on the segmented texts with a dimensionality of 100. Keywords with a similarity score of 0.85 or higher are selected to expand and enrich green-washing information.

Fourth, matching selective disclosure and expressive manipulation.

MD&A texts are split into sentences, and sentence vectors are calculated using a weighted average of word vectors. Sentences are classified as hard or soft green-washing information when similarity with target green-washing sentences exceeds 0.8.

Fifth, measuring firm green-washing behavior.

The number of green-washing disclosure items is counted, and the proportions of selective disclosure and expressive manipulation are computed. The natural logarithm of their geometric mean is used to measure corporate green-washing, with higher positive scores indicating more serious green-washing behaviors.

3.2.4. Control variables

The control variables include firm size, cash flow from operating activities, firm age, ownership category, Tobin Q, market position, and environmental protection investment. The specific definitions and calculation methods are shown in Table 2.

Table 2. Selection and definition of major variables.

Variable type	Variable name	Variable symbol	Variable definition
Explained variable	Firm green transformation	FGT_{it}	The cumulative probability value of green transformation-related themes in the MD&A texts
Explanatory variable	Government green attention	GGA_{it}	The cumulative word frequency of green theme keywords × 100/ total words amount in GWR texts
Influence mechanism	Environmental information disclosure	EID_{it}	The actual score of environmental information disclosure/25
	Firm green innovation	GI_{it}	The natural logarithm of (number of applied green patents+1)
	Firm green-washing behavior	GWS_{it}	The natural logarithm of corporate green-washing degree
Control variables	Firm size	$size_{it}$	The natural logarithm of total assets value
	Cash flow from operations	cfo_{it}	Net cash flow from operating activities/total assets value
	Firm market value	Q_{it}	Firm market value / capital replacement cost
	Firm age	age_{it}	The natural logarithm of firm age since initial public offering
	Ownership type	$\mathrm{so}e_{it}$	1 if the firm's actual controller is state-owned $\mathrm{so}e_{it}$, 0 otherwise $\mathrm{so}e_{it}$
	Market power	mp_{it}	1 if the ratio of firm's annual sales revenue to industry sales is greater than the median of the mp_{it} industry, 0 otherwise mp_{it}
	Environmental protection investment	epi_{it}	Total investment in urban environmental pollution control/urban GDP

3.3. Research method

Local government environmental attention enhances firm green investment and ESG performance (Chen et al., 2024a; Liu et al., 2024). It also improves firms' carbon reduction actions and promotes carbon emission governance (Liu et al., 2023b; Zhu et al., 2023). Building on these studies, we extend the green transformation dictionary to measure GGA and FGT using textual analysis. Unbalanced panel data with fixed effects are used to explore the impact of GGA on FGT. Its research model is written as follows:

$$FGT_{it} = c + \alpha GGA_{it} + \sum_{j=1}^{7} \beta_j X_{it} + \gamma_i + \sigma_c + \zeta_{it} \tag{3}$$

The firms and years are denoted by i and t, respectively. FGT_{it} is the explained variable, firm green transformation, and GGA_{it} is the explanatory variable, government's green attention. The vector of control variables is denoted as X_{it}. $\gamma_{\text{i}}, \sigma_c$ represents industry and city fixed effects, respectively, and ζ_{it} is the random disturbance term.

To examine the channels and mechanisms of the relationship between GGA and FGT, we further explre the mediating effects of firm environmental disclosure (EID_{it}), firm green innovation (GI_{it}), and corporate green-washing behavior (GWS_{it}) by constructing equations (3) and (4), testing whether the strength of GGA's effect on FGT varies. Their influence mechanism models are expressed as follows:

$$Y_{it} = c + \alpha GGA_{it} + \sum_{j=1}^{7} \beta_j X_{it} + \gamma_i + \sigma_c + \zeta_{it} \tag{4}$$

$$FGT_{it} = c + \alpha_1 GGA_{it} + \alpha_2 Y_{it} + \sum_{j=1}^{7} \beta_j X_{it} + \gamma_i + \sigma_c + \zeta_{it} \tag{5}$$

Here, Y_{it} refers to the above three influence mechanism variables, respectively.

4. Empirical results analysis and discussion

4.1. Descriptive statistics

The descriptive statistics of the major variables are presented in Table 3. The mean of FGT is 0.1506, with a standard deviation of 0.2161, indicating substantial variation in firm green transformation. The mean of GGA is 0.0093, with a standard deviation of 0.0023. Compared with FGT, GGA exhibits lower variability and shows a time-varying trend. Overall, the minimum, maximum, and standard deviation values of the firm samples are within reasonable ranges.

Table 3. Descriptive statistics of major variables.

Variable	Samples	Mean	Standard Deviation	Minimum	Maximum
FGT_{it}	30057	0.1506	0.2161	0.0000	1.2745
GGA_{it}	30057	0.0093	0.0023	0.0048	0.0161
CSR_{it}	30057	0.4724	0.2522	0.0000	0.8333
GI_{it}	30057	0.3125	0.7131	0.0000	6.3544
GWS_{it}	12,757	−0.0429	0.6942	−5.5460	4.7336
$size_{it}$	30057	22.3260	1.2779	19.9761	26.2862
cfo_{it}	30057	0.0487	0.0656	−0.1388	0.2381
Q_{it}	30057	2.0874	1.3560	0.8335	8.6635
age_{it}	30057	2.3161	0.6785	1.0986	3.4012
$\mathrm{so}e_{it}$	30057	0.3960	0.4891	0.0000	1.0000
mp_{it}	30057	0.1192	0.1326	−0.3383	0.5329
epi_{it}	30057	0.0162	0.0063	0.0035	0.0380

4.2. Fundamental results

Table 4 presents the correlation results between the major variables. GGA and FGT are significantly positively correlated, confirming that higher government green attention promotes firm green transformation. The absolute values of all correlation coefficients are below 0.4000, indicating no multicollinearity issues among the major variables.

Table 4. The correlation relationship of major variables.

	FGT_{it}	GGA_{it}	$size_{it}$	cfo_{it}	age_{it}	$\text{so}e_{it}$	Q_{it}	mp_{it}	epi_{it}
FGT_{it}	1								
GGA_{it}	0.0820***	1							
$size_{it}$	0.0801***	0.0452***	1						
cfo_{it}	−0.00860	−0.0026	0.1118***	1					
age_{it}	−0.0370***	0.0180**	0.3801***	−0.0065	1				
$\text{so}e_{it}$	−0.0260***	−0.0147**	0.3087***	−0.0259***	0.4110***	1			
Q_{it}	−0.0756***	−0.0321***	−0.4093***	−0.0855***	−0.0998***	−0.1580***	1		
mp_{it}	0.0347***	0.0015	0.0827***	0.3844***	−0.1758***	−0.1139***	0.1056***	1	
epi_{it}	0.0920***	0.0900***	0.0114***	−0.0032	−0.0339***	−0.1011***	−0.0015	0.0204***	1

Table 5 reports the empirical results of the fundamental effect of GGA on FGT. The empirical results in the three columns are based on panel data, controlling for industry fixed effects, city fixed effects, and both industry and city fixed effects.

In column (1), under industry fixed effects, the coefficient of GGA is 6.2220, indicating that GGA significantly promotes firm green transformation at the 1% significance level. In column (2), when controlling for city fixed effects, the coefficient of GGA increases to 7.0303, suggesting that the promotion effect of GGA on FGT is stronger than that under industry fixed effects. In column (3), when both industry and city fixed effects are controlled, the coefficient of GGA is 6.9062, showing that an increase in GGA can significantly promote FGT at the 1% significance level.

Higher GGA encourages local government decision-makers to introduce green policy support in areas such as green fiscal and tax incentives, green finance, environmental governance, and sustainable development. These policies motivate firms to actively pursue green transformation in order to obtain more resource support. Increased resource input promotes FGT, strengthens market confidence, and enhances future firm profitability. Higher GGA also increases the intensity of environmental regulation and external institutional pressure, encouraging firms to expand green investment and improve green transformation performance. Favorable information improves firms' social image and market trust among stakeholders, motivating investors to optimize their investment portfolios and enabling firms to obtain more resources from capital markets.

In addition, higher GGA attracts greater public and stakeholder attention to green governance and green transformation, strengthening social supervision pressure. This pressure forces firms to implement green governance actions, improve green transformation performance, enhance social relationships with stakeholders, and strengthen corporate social responsibility, thereby creating sustainable competitive advantages. Firm green transformation is influenced not only by current green policies but also by the continuity of previous policies. It relies on long term policy adaptation and the gradual implementation of green innovation processes. Long term green policy support and resource allocation more effectively promote green transformation performance.

Moreover, firm size, firm age, market position, and urban environmental investment positively affect FGT at the 1% significance level, while operating cash flow, ownership type, and Tobin's Q negatively affect FGT at the 1% significance level. These results indicate significant differences in green governance behavior across firms with different characteristics. Larger firms and firms with stronger market power tend to be more proactive in green transformation due to greater resource availability, stronger innovation capacity, and better access to government policy support. Older firms are more inclined to engage in green transformation because of accumulated capital, management experience, and market reputation, as well as greater attention to long term sustainability. Firms with higher operating cash flow are less likely to engage in green transformation due to high upfront costs and operational risks. Firms with higher market value tend to maintain their existing competitive advantages and are less willing to improve green transformation performance through additional green governance actions.

Table 5. The empirical results of GGA on FGT.

Variable	FGT_{it} *(1)*	FGT_{it} *(2)*	FGT_{it} *(3)*
Intercept term	−0.1526***	−0.2602***	−0.2124***
	(−5.83)	(−9.56)	(−7.84)
GGA_{it}	6.2220***	7.0303***	6.9062***
	(11.80)	(11.62)	(11.72)
$size_{it}$	0.0092***	0.0125***	0.0102***
	(7.75)	(10.17)	(8.33)
cfo_{it}	−0.0752***	−0.0954***	−0.0711***
	(−3.70)	(−4.60)	(−3.47)
Q_{it}	−0.0065***	−0.0070***	−0.0051***
	(−6.51)	(−6.77)	(−5.02)
age_{it}	0.0064***	0.0048**	0.0076***
	(3.00)	(2.14)	(3.44)
soe_{it}	−0.0261***	−0.0181***	−0.0252***
	(−9.23)	(−5.99)	(−8.36)
mp_{it}	0.0436***	0.0620***	0.0349***
	(4.20)	(5.84)	(3.31)
epi_{it}	2.9375***	4.5877***	4.5009***
	(15.14)	(16.81)	(16.91)
Fixed effect	Industry	City	Industry and city
R^2	0.0790	0.0450	0.0960
Observations	30057	30049	30049

Note: The values in parentheses are t statistics, *, * *, and * * * indicate significance at the 10%, 5%, and 1% levels, respectively.

4.3. Endogeneity test

There may be a bidirectional causal relationship between GGA and FGT, and the omission of key variables, such as local government fiscal incentives GEF_{it} and the green transformation of peer firms, may lead to biased estimation results. Combining environmental regulations with green fiscal policies, including government subsidies and tax rebates, can create a synergistic effect in environmental governance, thereby reducing the overall cost of corporate green transformation. Here, we use the proportion of local government fiscal expenditure on environmental governance relative to the general fiscal budget as an external environmental policy shock. The green transformation of peer firms can attract green technology, talent, and capital, thereby reducing regional green transformation costs and prompting local governments to adopt more proactive green governance policies. Peer firms' FGT may influence local government environmental governance policies and further strengthen the relationship between GGA and FGT. We select the average level of peer firms' green transformation as an indicator of this reverse facilitating effect. The endogeneity results for GGA and FGT are estimated using the TwoStage Least Squares method with instrumental variables, as shown in Table 6.

When local government green fiscal policies and peer firms' FGT are used as instrumental variables, the validity tests indicate that the KleibergenPaap rk LM statistics are 201.6495 and 377.9967, respectively, both rejecting the underidentification hypothesis at the 1% significance level. In addition, the KleibergenPaap rk Wald F statistics are 224.1031 and 465.2489, respectively, exceeding the critical value of 16.38 at the 10% significance level, demonstrating local government green fical policies and peer firms' FGT as instrument variables are strongly related with endogenous explanatory variables. These results indicate that there is no weak instrumental variable problem and that the instrumental variable selection is appropriate. In column (1), the coefficient of GEF_{it} environmental fiscal incentive is 0.0440, indicating that local government environmental fiscal incentive policies significantly enhance GGA at the 1% significance level. In column (2), after excluding the external policy shock of environmental fiscal incentives, the coefficient of GGA_{it} GGA is 39.1901, which is significantly higher than 6.9062 in column (3) of Table 5. These results confirm that even after excluding the effect of environmental fiscal incentive policies, higher GGA still significantly promotes corporate green transformation. In column (3), the coefficient of peer firms' FGT FGT_{it} is 0.1608, indicating that peer firms' green transformation significantly improves GGA at the 1% significance level. Through energy conservation, emission reduction, green product development, and brand image enhancement, peer firms convey positive signals to local governments regarding the economic feasibility of green policies. These green behaviors reshape industry competition and establish new green technology standards, raising environmental expectations among consumers, investors, media, and the public, and increasing pressure on local governments to strengthen environmental supervision and governance. In column (4), the coefficient of GGA is 135.7757, confirming that GGA significantly promotes FGT after excluding the influence of peer firms' green transformation. First, peer firms' FGT encourages local governments to implement stricter emission standards, increase pollution charges, strengthen law enforcement, and intensify environmental regulation, thereby further promoting firm green transformation. Second, peer firms' FGT motivates local governments to cultivate green market demand through measures such as public procurement, energy efficiency labeling, green product certification, and economic incentives. These measures improve information transparency and market reputation, encouraging firms to pursue or maintain leadership in green transformation.

Economic, environmental, and social factors are important drivers of green transformation in the European Union, China, and the United States (Cheba et al., 2023; Chen, 2024; Gawel et al., 2024). Government environmental attention promotes regional green transformation in China by increasing environmental governance expenditure and improving public environmental services (Man et al., 2024). Environmental governance policies also exhibit a U-shaped nonlinear relationship with industrial green transformation (Yang et al., 2023). Climate and energy targets and green policies in the EU and China are crucial drivers of corporate green transformation performance (Li and Wu, 2024; Oberthür and Kulovesi, 2025). Market oriented environmental regulation further enhances FGT performance (Chen, 2024; Ma et al., 2025). This study enriches the literature on the relationship between GGA and FGT from the perspective of government regulation.

Table 6. Results of the endogeneity test using the instrumental variable method.

Variable	GGA_{it} (1)	FGT_{it} *(2)*	GGA_{it} (3)	FGT_{it} *(4)*
	First stage	Second stage	First stage	Second stage
Intercept term	0.0080***	−0.4086***	0.0085***	−1.1037***
	(34.37)	(−5.48)	(36.06)	(−11.75)
GEF_{it}	0.0440***			
	(16.29)			
GGA_{it}		39.1901***		135.7757***
		(4.97)		(15.79)
Peer FGT			0.1608***	
			(29.41)	
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Industry and city	Industry and city	Industry and city	Industry and city
KleibergenPaap rk LM statistic	201.6495***		377.9967***	
Kleibergen-Paap Wald rk F statistic	224.1031		465.2489	
Observations	30049	30057	30049	30057
R^2	0.2320	0.0920	0.2590	0.1900

4.4. Robustness results

To improve the reliability of the results and reduce the impact of measurement errors, we conduct robustness tests using three approaches: alternative FGT measurement, lagged GGA effects, and a placebo test. The robustness test results are reported in Table 7.

First, we report results without tail-shrinking to eliminate sample selection bias. In column (1), the coefficient of GGA is 6.9004. Compared with 6.9062 in column (3) of Table 5, the promotion effect of GGA on FGT slightly weakens but remains significant at the 1% level. This indicates strong robustness after excluding firms with abnormal financial data.

Based on the quantitative FGT measurement method proposed by Lin and Pan (2024), we select five primary indicators and eight secondary indicators to reduce measurement error in the explained variable. The primary indicators include green innovation, clean production, pollutant and carbon emission reduction, environmental protection, and social evaluation. The secondary indicators include innovative investment, innovative output, labor productivity, pollutant emission control, cleaner production, environmental management, environmental regulation, and social responsibility. After standardizing the eight secondary indicators, the entropy weight method is applied to construct a comprehensive FGT index. In column (2), the coefficient of GGA is 1.2250, indicating that a higher GGA level significantly promotes quantitative FGT, demonstrating good robustness.

When governments allocate different levels of attention to green transformation across periods, local firms may adopt speculative strategies by choosing periods with relatively loose environmental regulation to avoid stricter green transformation requirements and achieve compliance. In columns (3), (4), and (5), we use the first, second, and third lagged values of GGA to examine robustness while accounting for dynamic effects and preceding trends. The coefficients of GGA are 6.3410, 6.0572, and 5.9543, respectively. The lagged GGA levels also significantly promote FGT at the 1% significance level, indicating strong robustness.

Additionally, we further introduce the exogenous policy shock of China's dual-carbon targets in 2020 to examine differences in the relationship between GGA and FGT before and after policy implementation. A difference indifferences method is employed, with results reported in column (6) of Table 7 . Firms in heavy-pollution industries $treat_i$ are assigned a value of 1, otherwise $treat_i$ are 0. Years after 2020 $post_t$ are assigned a value of 1, otherwise $post_t$ are 0. In column (6), the coefficient of GGA_{it} GGA is 6.4075. After excluding the impact of the dual-carbon targets, the promotion effect of GGA on FGT shows a slight decline compared with column (3) of Table 5, but remains robust. The coefficient of DID_{it} $post_t$ $treat_i$ shows that the interaction term is 0.0757, indicating that the dual-carbon targets have a significant and positive impact on FGT at the 1% significance level.

Table 7. Empirical results of robustness tests for GGA and FGT.

Variable	FGT_{it} (1)	FGT_{it}^1 (2)	FGT_{it} (3)	FGT_{it} (4)	FGT_{it} (5)	FGT_{it} (6)
Intercept term	−0.2785*** (−10.08)	−0.4714*** (−36.63)	−0.2069*** (−7.58)	−0.2028*** (−7.39)	−0.1997*** (−7.24)	−0.1819*** (−6.70)
GGA_{it}	6.9004*** (10.81)	1.2250*** (4.38)				6.4075*** (10.87)
$GGA_{i(t-1)}$			6.3410*** (10.66)			
$GGA_{i(t-2)}$				6.0572*** (10.07)		
$GGA_{i(t-3)}$					5.9543*** (9.81)	
DID_{it}						0.0757*** (11.37)
Control variable	Yes	Yes	yes	Yes	yes	Yes
Fixed effect	Industry and city	Industry and city	Industry and city	Industry and city	Industry and city	Industry and city
R^2	0.1890	0.2220	0.0950	0.0940	0.0940	0.0100
Observations	31049	30049	26179	22733	19654	30049

Note: FGT_{it}^1 *is a quantitative FGT measurement using Lin and Pan's method.*

To mitigate the impact of unobservable omitted variables on the fundamental regression results, we substitute the GGA levels of the experimental group using the approach proposed by Cai et al. (2016) and conduct a placebo test. The placebo test procedure is repeated 1,000 times, generating kernel density distributions and corresponding p-values for the 1,000 coefficient estimates. Figure 4 reports the density distribution of p-values for the "pseudo" GGA levels in relation to the FGT regression coefficients. The black vertical line in Figure 4 represents the true regression coefficient between GGA and FGT, as reported in column (3) of Table 4. The randomized regression coefficients are predominantly concentrated around zero, with most p-values exceeding 0.05, indicating that the randomized regression results are not statistically significant. Moreover, all randomized estimated coefficients lie to the left of the true estimated value, indicating that the coefficient estimate from the fundamental regression is located in the upper tail of the distribution of placebo regression coefficients. This outcome represents a low probability event in the placebo test for GGA. Therefore, after implementing the randomization treatment, the relationship between GGA and FGT is considered robust.

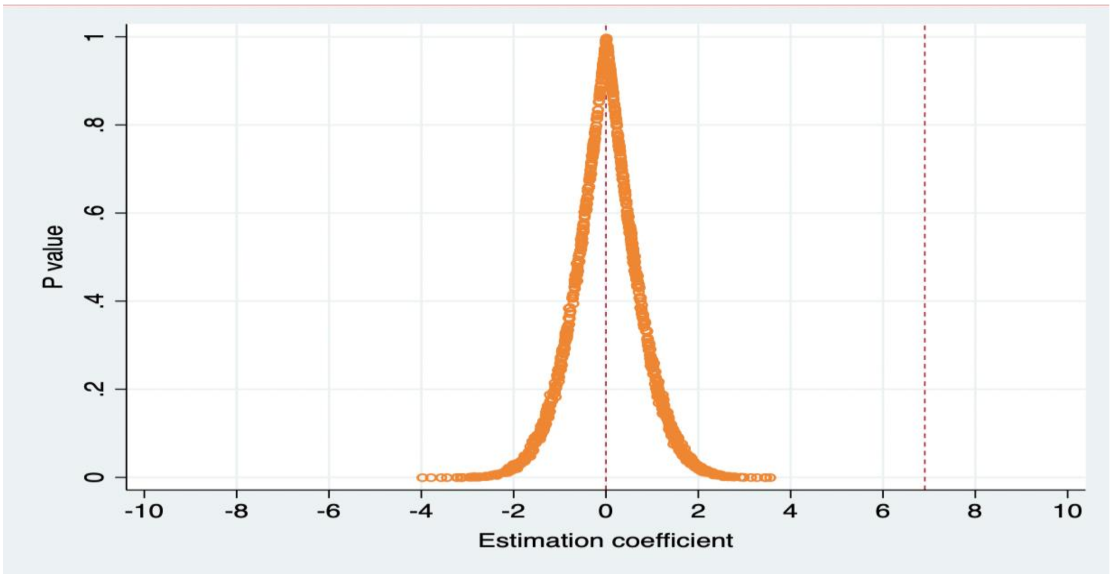

Figure 4. Placebo test of the nexus between GGA and FGT.

4.5. Influence mechanism results

Based on the theoretical analysis, we explore the influence mechanisms linking GGA to FGT through three dimensions: corporate environmental information disclosure, corporate green innovation, and corporate green-washing behaviors. The corresponding results are reported in Table 8.

(1) Improving corporate environmental information disclosure

In column (1), the coefficient of GGA is 39.3970, indicating that GGA significantly enhances corporate environmental information disclosure at the 1% level. In column (2), the CSR_{it} coefficients of GGA and corporate environmental information disclosure are 5.9683 and 0.0238, respectively, with both significant at the 1% level. These results suggest that GGA promotes FGT by improving corporate environmental information disclosure.

When local governments attach greater importance to green transformation, firms are incentivized to improve the quality and extent of their environmental information disclosure. Higher GGA implies increased policy support for green development, stricter environmental regulation, and stronger legal supervision. Consequently, firms are required to regularly disclose information on environmental impacts, pollution control measures, and green development achievements through laws and regulations. Moreover, increased GGA strengthens stakeholder supervision over firms' green transformation efforts, raises external regulatory pressure, and motivates firms to disclose more comprehensive environmental information. Positive environmental disclosures, such as information on energy conservation, greenhouse gas and pollutant emissions, and environmental governance measures, can significantly enhance firms' green transformation performance.

(2) Boosting corporate green innovation

In column (3), the coefficient of GGA is 5.0946, indicating that GGA significantly strengthens corporate green innovation output. This result confirms that when local governments place greater emphasis on sustainable development and green governance, firms increase the input and efficiency of green innovation. In column (4), the coefficients of GGA and GI_{it} corporate green innovation are 6.8002 and 0.0208, respectively, with both significant at the 1% level, indicating that GGA promotes FGT by enhancing corporate green innovation.

Higher GGA increases policy support for green development and improves resource allocation toward green transformation. These advantages incentivize firms to increase investment in green technology research and development, strengthen green innovation capacity, and enhance green innovation output. Green innovation can offset additional operational costs and risks associated with environmental regulation, attract greater support from stakeholders, and improve access to resources through market and non-market channels. As a result, higher GGA encourages firms to achieve greater economic and environmental benefits by promoting corporate green innovation.

(3) Inhibiting corporate green-washing behaviors

In column (5), the coefficient of GGA is −2.2002, indicating that GGA significantly restrains corporate green-washing behaviors at the 1% level. Stronger GGA is associated with stricter environmental supervision, which increases the likelihood that firms engaging in green-washing will incur economic penalties, thereby reducing such behaviors. In column (6), the coefficients of GGA and corporate green-washing behaviors GWS_{it} are 0.4157 and −0.0395, respectively. The results show that greater green-washing behavior significantly inhibits FGT at the 1% level, as firms weaken the long-term effectiveness of green transformation through misleading green advertising. These findings indicate that higher GGA enhances FGT by suppressing corporate green-washing behaviors.

Moreover, higher GGA strengthens legal supervision and the intensity of environmental regulation, increasing the risks and additional costs associated with green-washing, which generates a stronger market deterrent effect. Moreover, higher GGA attracts greater stakeholder attention to green transformation and creates stronger external monitoring pressure, thereby promoting improvements in FGT. By discouraging corporate green-washing behaviors, higher GGA contributes to lower levels of green-washing, which in turn facilitates firm green transformation. Therefore, higher GGA can promote FGT by alleviating corporate green-washing behaviors.

Table 8. Results of the influence mechanisms between GGA and FGT.

Variable	EID_{it} (1)	FGT_{it} (2)	GI_{it} (3)	FGT_{it} (4)	GWS_{it} (5)	FGT_{it} (6)
Intercept term	−6.0757***	−0.0681**	−2.9387***	−0.1512***	3.3596***	0.0223
	(−60.07)	(−2.38)	(−36.25)	(−5.47)	(46.30)	(0.52)
GGA_{it}	39.3970***	5.9683***	5.0946***	6.8002***		
	(17.92)	(10.11)	(2.89)	(11.56)		
$GGA_{i(t-1)}$					−2.2002***	0.4157***
					(−21.41)	(7.02)
EID_{it}		0.0238***				
		(15.37)				
GI_{it}				0.0208***		
				(10.75)		
GWS_{it}						−0.0395***
						(−11.81)
Control variable	yes	yes	yes	Yes	yes	yes
Fixed effect	Industry and city	Industry and city	Industry and city	Industry and city	Industry and city	Industry and city
R^2	0.2040	0.0990	0.1790	0.0990	0.2230	0.2850
Observations	30049	30049	30049	30049	29555	29555

4.6. Heterogeneity tests

(1) Nature of firm ownership

The nature of firm ownership plays an important role in shaping the relationship between GGA and FGT. The full sample is divided into two subsamples, state-owned firms and non-state-owned firms, to examine whether ownership type leads to significant differences in this relationship. The heterogeneity results are reported in columns (1) and (2) of Table 9.

Columns (1) and (2) show that GGA significantly enhances green transformation for state-owned and non-state-owned firms at the 1% level, confirming the existence of ownership-based heterogeneity. Moreover, compared with state-owned firms, GGA exerts a stronger promoting effect on FGT for non-state-owned firms.

First, state-owned and non-state-owned firms differ substantially in their perception of policy pressure and their capacity to access resources. State-owned firms maintain stronger political connections with local governments, enabling them to obtain greater green policy support and preferential resource allocation. These firms are more motivated to contribute to local economic growth and employment stability, but they exhibit weaker incentives to rely on green governance activities to improve green transformation performance. As a result, the effect of GGA on FGT is relatively weaker for state-owned firms. In contrast, non-state-owned firms operate with greater flexibility and innovation and are more responsive to government green policies and green attention. Consequently, they gain stronger incentives to promote resource reallocation through green transformation.

Second, significant differences exist between state-owned and non-state-owned enterprises with respect to market deterrence and financing constraints. Local governments tend to show higher tolerance toward environmental violations by state-owned firms, resulting in less stringent penalties and enforcement intensity, thereby weakening market deterrence in green transformation. Conversely, when non-state-owned firms commit environmental violations, local governments impose heavier fines and stricter regulatory measures, forcing these firms to accelerate green transformation. In addition, non-state-owned firms rely more heavily on market-based financing channels, such as bank loans, bond issuance, and equity financing, and therefore use green transformation performance to alleviate financing constraints and reduce financing costs. State-owned firms, by contrast, have greater access to policy-based financing and face weaker market financing constraints. These findings suggest that local government decision- makers should account for ownership heterogeneity when formulating and implementing green policies and provide more targeted support measures to promote comprehensive green transformation.

(2) Firm size

Significant heterogeneity exists between large companies and small- and medium-sized enterprises (SMEs) in terms of their responsiveness to government policies and the effectiveness of green transformation. The classification follows the "Method for Classifying Large, Medium, Small, and Micro Enterprises" published by the National Bureau of Statistics. In this study, companies with annual revenues exceeding 400 million Yuan are classified as large, while the remaining firms are considered small and medium-sized. The heterogeneity results are reported in columns (3) and (4) of Table 9. Compared with large companies, the GGA has a more pronounced impact on promoting green transformation in small- and medium-sized firms. Differences in regulatory pressure perception, flexibility in decision-making, and market reputation are the major factors driving this heterogeneity between GGA and firms of different sizes.

First, relative to large companies, SMEs must accelerate their green transformation efforts to avoid higher compliance costs or the risk of closure when GGA increases environmental regulatory pressure. Moreover, SMEs can obtain resource support through green transformation performance, including green credit, technology upgrade subsidies, and tax incentives.

Second, SMEs generally have flatter management structures and more centralized decision-making authority, enabling greater flexibility in implementing green transformation activities. Third, compared to large companies, SMEs are more motivated to leverage green transformation to enhance market opportunities and social reputation, generating greater marginal benefits from their green initiatives.

Table 9. Heterogeneity analysis results on ownership type and firm size.

Variable	FGT_{it} (1)	FGT_{it} (2)	FGT_{it} (3)	FGT_{it} (4)
	State-owned	Non-state-owned	SME firms	Big firms
Intercept term	−0.1760***	−0.2686***	−0.1943***	−0.0501
	(−4.11)	(−7.06)	(−6.65)	(−0.31)
GGA_{it}	5.4751***	7.7528***	6.8758***	6.6579***
	(5.91)	(10.18)	(10.95)	(4.06)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Industry and city	Industry and city	Industry and city	Industry and city
R^2	0.1310	0.0870	0.099	0.087
Observations	11901	18146	27484	2542

(3) Polluting Firms

Firms in industries with different pollution levels show significant differences in environmental policy response, green investment, green innovation capacity, and public supervision. In this study, the sample is divided into two sub-samples: firms in heavy- pollution industries and firms in non-heavy -pollution industries. The heterogeneity results are shown in columns (1) and (2) of Table 10.

In columns (1) and (2) of Table 10, the GGA level positively impacts the green transformation of heavy-pollution and non-heavy-pollution firms, indicating significant differences. The promotion effect of GGA on heavy-pollution firms is greater than that on non-heavy-pollution firms.

First, the internalization of external costs affects polluting and non-polluting firms differently. The GGA requires firms to bear the costs of pollution governance through command-and-control policies, such as emission standards and production limits, or market-based incentive policies, such as carbon taxes and emissions trading. Heavy-pollution firms face higher regulatory intensity and external policy pressure to reduce non-compliance costs, such as penalties and pollution governance costs, and technological risks. Moreover, GGA encourages non-heavy-pollution firms through positive policies and market incentives, helping them reduce long-term operational costs, gain a competitive advantage with green products, enhance brand image, and increase market share.

Second, the cost-benefit balance of green transformation differs between heavy-polluting and non-heavy-polluting firms. Heavy-pollution firms experience greater compliance pressure, resulting in higher marginal benefits from GGA, which strongly enhances FGT performance. Non-heavy-pollution firms face lower marginal benefits, so the promotion effect of GGA on FGT is smaller.

(4) GGA Level

Based on the median of GGA, the sample is divided into two sub-samples: lower GGA and higher GGA. The heterogeneity results are presented in columns (3) and (4) of Table 10. The coefficients for lower GGA and higher GGA are 6.1933 and 7.6762, respectively, showing that higher GGA has a stronger promotion effect on FGT at the 1% significance level.

First, different GGA levels generate varying policy signals and regulatory intensity regarding green transformation. Local governments with higher GGA implement stricter environmental regulations, including tighter emission standards, frequent inspections, rigorous enforcement, and public disclosure of violations. These measures incentivize firms to invest in technological improvements and equipment upgrades, accelerating their green transformation. In contrast, local governments with lower GGA adopt advisory or principle-based approaches, relying on vague and inconsistent policy signals. This softer enforcement leads to weaker regulatory intensity and a reduced effect on promoting corporate green transformation.

Second, regions with higher GGA provide stronger green policy support and greater resource allocation, enabling firms to carry out green transformation more effectively. Higher GGA also attracts greater public attention to environmental issues, increasing external pressure on firms. This encourages companies to adopt green innovation and sustainable development measures to maintain their social image and market competitiveness. Conversely, regions with lower GGA offer limited support and fewer market-based incentives, leaving firms to bear most transformation costs, which leads to lower FGT performance.

Table 10. Heterogeneity analysis results on polluting firms and GGA level.

Variable	FGT_{it} (1)	FGT_{it} (2)	FGT_{it} (3)	FGT_{it} (4)
	Polluting firms	Non-Polluting Firms	Lower GGA	Higher GGA
Intercept term	−0.3441***	−0.1605***	−0.1611***	−0.2481***
	(−5.98)	(−5.07)	(−5.27)	(−3.59)
GGA_{it}	9.3675***	5.6974***	6.1933***	7.6762***
	(8.35)	(8.25)	(6.32)	(2.76)
Control variables	Yes	Yes	Yes	Yes
Fixed effect	Industry and city	Industry and city	Industry and city	Industry and city
R^2	0.1440	0.0830	0.0840	0.1330
Observations	8548	21489	22517	7512

5. Conclusions and policy implications

5.1. Conclusions

FGT has attracted increasing attention from firms and society, particularly as local governments enhance their GGA. Based on empirical evidence from A-share firms listed on the Shanghai and Shenzhen Stock Exchanges from 2010 to 2022, we investigate the impact of GGA on FGT. The major findings are summarized as follows:

1. **Positive effect of GGA on FGT:** The results confirm that GGA has a significant and positive impact on FGT. Higher GGA strengthens government policy guidance and environmental supervision, encouraging firms to adopt greener practices and pursue sustainable development.
2. **Transmission mechanisms:** Firm green innovation, environmental information disclosure, and the inhibition of green-washing behaviors serve as significant channels linking GGA to FGT. Specifically: Higher GGA motivates firms to increase green innovation and environmental information disclosure at the 1% significance level. Green innovation improves resource efficiency, reduces environmental pollution, and facilitates cleaner production, accelerating FGT. Transparent environmental information disclosure enhances social trust, strengthens brand reputation, attracts stakeholder support, and improves market competitiveness, further promoting FGT. Higher GGA inhibits green-washing behaviors at the 1% significance level. Stricter legal regulations and stronger market deterrence reduce false green claims, thereby encouraging genuine green transformation.
3. **Heterogeneity effects:** The impact of GGA on FGT varies across firms:

Ownership: Non-state-owned firms respond more actively to GGA than state-owned firms, motivated by the desire to enhance social image, governance quality, and market competitiveness.

Pollution intensity: Non-heavy-polluting firms can more effectively implement environmental technologies and management methods, whereas heavy-polluting firms face higher compliance costs.

GGA intensity: Higher GGA levels generate stronger policy pressure, public supervision, and economic incentives, promoting greater green transformation performance.

5.2. Policy implications

Our findings offer several practical implications for government decision-makers, market regulators, and firms:

1. **Strengthen government policy support:**

Local governments should continue to prioritize green governance and encourage firms to invest in green innovation through policies such as stricter environmental regulations, financial supports, subsidies, and tax incentives. Special green technology funds can support small and medium-sized enterprises (SMEs) to boost their innovation capacity and participation in green market competition. Differentiated policy designs that account for regional and industry-specific characteristics will enhance policy effectiveness, fairly distribute transformation costs, and promote sustainable development.

2. **Enhance environmental information disclosure requirements:**

Regulatory authorities should establish stricter environmental disclosure standards, requiring firms to report environmental measures, carbon emissions, and green technology applications regularly. Accurate disclosure reduces green-washing risks and provides stakeholders, including investors and consumers, with reliable information to make informed decisions.

3. **Prevent and reduce green-washing behaviors:**

Governments and regulators should strengthen oversight of environmental claims and publicity to prevent misleading or exaggerated green messaging. Establishing comprehensive evaluation and punishment mechanisms for green-washing, including lowering environmental ratings, public criticism, or revoking green qualifications, will reinforce fairness and transparency, encouraging firms to genuinely enhance their green transformation.

Author contributions

Kai Chang provides the overall study framework, and writes and revised the manuscript.

Haoxuan Fu measures the GCA and FGT data and collects firm panel data, and provides the empirical results.

Wenqi Wang provides other financial data and related literatures overviews.

Use of AI tools declaration

This study uses Anacoda3 software to qualitatively measure GCA and FGT data, and uses Stata software to conduct empirical results on corporate panel data. We promise not to use AI tools to organize the content of our manuscript.

Acknowledgments

Humanities and Social Science Fund of the Ministry of Education of China (25YJA790002).

Conflict of interest

The authors declare no conflict of interest.

Data Availability Statement

The related textual big data of corporate MD&A and local government working reports (GWR) are sourced from the Shanghai and Shenzhen Security Exchange platform, China Research Data

Services (CNRDS) database and government website . Data on the mediating variables and control variables were all sourced from the Wind and the China Stock Market and Accounting Research (CSMAR) database. The data avaliability is requested for the conresponding authors.

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