The Impact of Government Environmental Attention to Green Technology Innovation?

ABSTRACT

Green innovation activities have become the focus of governments with global climate change and increasing environmental pollution. Governments around the world are paying more concern to environmental issues, which promotes the development of green innovation activities. Only a few literatures have studied the influencing factors of green technology innovation (GTI) from a government environmental attention (GEA) perspective. Thus, this study aims to explore the relationship between GEA and GTI by using city-level panel data from 2004 to 2020 in China. According to theoretical analysis and empirical tests, we examine how, and through what influencing mechanisms, GEA affects the development and adoption of GTI. Based on the rough data analysis, we found thatt: (1) GEA plays a beneficial role in promoting GTI, and the results are robust after considering endogeneity and further robustness test. (2) The impact of GEA on GTI is heterogeneous. Relatively speaking, for cities in coastal, high-level economic development, and high-level agglomeration areas, the positive influence of GEA on GTI is more obvious. (3) The mechanism test shows that GEA has the potential to indirectly support GTI by easing financing constraints and promoting industrial structure upgrading. Overall, our study will enhance the importance of government attention to environmental issues in promoting GTI.

Keywords: Government environmental attention; Green technology innovation; Heterogeneity analysis; Mechanism analysis

1. Introduction

The present-day global energy system is confronted with considerable challenges and uncertainties in the 1970s. Against this backdrop, the energy development of China is beset by a range of complex and multifaceted challenges. According to bp's Statistical Review of World Energy (2022), China remains the world's largest energy consumer with a 26.49% share of primary energy consumption and a 31.06% share of carbon dioxide emissions in 2021. To reconcile the competing demands of economic development and environmental protection, governments have been strengthening their efforts to protect the environment through environmental regulation, financial and taxation policy, upgrading industrial structure, and other methods (Dong et al., 2022; Su and Zhang, 2020; Wang et al., 2021; Wang et al., 2022; Wu et al., 2022; Zhao et al., 2020; Zhou et al., 2019). Among these efforts, promoting GTI is considered a key factor in achieving sustainable low-carbon development (Lee et al., 2022; Xu et al., 2023). GTI can not only promote industrial transformation but also improve resource utilization efficiency and reduce the environmental burden on businesses and individuals (Anthonissen et al., 2016; Fang, 2023; Miao et al., 2017; Zhang et al., 2020). Therefore, governments around the world are actively promoting the development of GTI and have formulated a series of related policies and measures. However, the attainment of GTI is a challenging endeavor. The R&D costs of green technology are substantially higher, while the technical complexity is greater, necessitating government support and guidance. Furthermore, the assurance of market demand is also imperative to circumvent the issue of non-commercialized technology.

The degree of GEA in GTI has a significant impact on the GTI's development. Previous research on GEA mostly focused on political science and public administration, sociology and psychology, with limited attention given to environmental science (Bao and Liu, 2022). Further investigation is necessary to explore the impact of GEA on environmental science, including how it affects the development of environmental policies, the implementation of environmental regulations and enforcement, the allocation of environmental funding and investments, and the promotion of public awareness and engagement. Only a few literatures have studied the relationship between GEA and GTI, but the research results have not yet reached a consensus (Chen et al., 2022a; Wu et al., 2022; Wu and Hu, 2020). Moreover, different governments attach different importance to GTI and adopt different policies, leading to significant differences in the level of GTI. This allows us to explore the impacts of GEA on GTI.

To better explore the relationship between GEA and GTI, this paper analyzes in-depth the role of GEA in the development of GTI. To begin, we generate indicators for GEA by collecting 297 government work reports and indicators for GTI at the city level. Second, we conduct a series of empirical tests to verify theoretical analysis, including baseline regression, endogenous analysis, and heterogeneity analysis. Third, we explore the impact mechanism between GEA and GTI. The results of this study have important theoretical and practical significance for promoting the development of GTI, strengthening the role of government in environmental protection, and achieving sustainable low-carbon development.

The contributions of this study are manifested as follows. First, the research perspective is unique. Different from the research before, this paper for the first time uses city-level data to discuss the relationship between GEA and GTI. The findings provide new empirical evidence, which complements the relevant analysis of GTI from a government perspective. Second, the measurement

of variables is reasonable. To conduct our research, we collect 297 government work reports at the city level from 2007 to 2020. We then utilize textual analysis to construct GEA, which can more accurately reflect the true attention and guidance of the local governments. Third, the empirical analysis is sufficient. We use fixed effect panel model and 2SLS regression to obtain an accurate estimation of the research. Additionally, we investigate the specific mechanisms and heterogeneous effects through GEA and GTI. Moreover, we use further robustness tests such as replacing core variables and changing the measurement methods to ensure the validity of empirical findings.

We organize the rest content as follows. Section 2 outlines a literature review on GEA and GTI. Section 3 introduces theoretical analysis and research hypothesis. Section 4 presents the methodology and data. Section 5 reports empirical results. Section 6 summarizes conclusions and policy implications.

2. Literature review

2.1. Research on GEA

Attention is an intersection concept that can be used in computer science, sociology and psychology science, political science and public administration (Jones, 1994; Posner and Rothbart, 2007; Yang, 2020). The governments deliver their attention in different ways, which in turn affects the development of different issues. The USA expresses government attention through the annual State of the Union (Cohen, 1995), The Britain expresses government attention through the "Speech from the Throne" (Kelso, 2017) China expresses government attention through the government work reports (Yang and Zheng, 2022). With the promotion of sustainable development and the protection of the environment, government attention to the environment is an important area of research.

The academic research on GEA includes three strands. The first strand discusses the economic factors and political systems are key drivers of GEA (Grossman and Krueger, 1995). Public pressure, such as public perceptions and media coverage, can influence government decision-making processes and increase GEA (Boudet et al., 2014; Trumbo, 1996). Furthermore, international cooperation and conventions, such as the Paris Agreement and the United Nations Framework Convention on Climate Change, can stimulate GEA by setting global environmental goals and standards (Haas et al., 1993; Hoffmann, 2011). The second strand discusses the strategies for GEA. Governments can adopt various strategies to promote environmental attention and develop effective environmental policies. Economic instruments, such as carbon taxes and subsidies for renewable energy, have been widely adopted by governments worldwide to incentivize the private sector to adopt more sustainable practices and technologies (Martelli et al., 2020). Regulatory measures have also been used to promote environmental protection (Zhao et al., 2015). The third discusses the impacts of GEA on environmental policies and outcomes. Studies have found that GEA can lead to increased investment in renewable energy, reduced greenhouse gas emissions, and improved environmental governance (Bao and Liu, 2022; Yang et al., 2020). Additionally, GEA can help to raise public awareness and promote sustainable behavior (Boudet et al., 2014).

2.2. Research on GTI

GTI is a process of developing new technologies and practices that reduce the negative

environmental impact of human activities. Existing literatures have provided a comprehensive analysis of GTI, including its drivers, barriers, and potential impacts on the environment and society. Environmental regulations have been found to be one of the main drivers of GTI (Borsatto and Amui, 2019; Luo et al., 2021). Stricter environmental regulations are more likely to invest in green technology innovation. Additionally, market demand and technological progress are also crucial drivers of GTI (Lin et al., 2014; Yang et al., 2022). However, the high cost of developing and implementing new technological progress may turn into barriers to GTI (Jaffe and Stavins, 1994). The lack of financial resources and access to funding can also be a significant barrier, particularly for small and medium-sized enterprises (Kivimaa and Kern, 2016). GTI also has the potential to have a significant impact on the environment and society. GTI can lead to reduced environmental impacts, improved resource efficiency, and new business opportunities (Schiederig et al., 2012). Additionally, GTI can contribute to the development of a more sustainable economy and create new jobs in green industries (Porter and Van Der Linde, 1995). The findings of this literature review highlight the key drivers and barriers of GTI, as well as its potential impacts. Continued investment and support are necessary to realize the full potential of GTI and achieve a more sustainable future.

3. Theoretical analysis and research hypothesis

3.1. GEA and GTI

GEA is the summary of the previous government work and the prospect of government work, which emphasizes the focus on work and policy. Current research on GEA primarily focuses on political science and public administration, economics and finance, sociology and psychology (Bao and Liu, 2022; Jones and Baumgartner, 2005; Lobao, 2016; Yu et al., 2020). Further investigation is necessary to explore the impact of GEA on environmental science, especially with the promotion of sustainable development and the protection of the environment. GEA exerts a substantial influence on environmental policies and outcomes. Studies have found that heightened government attention to environmental concerns can engender increased investments in renewable energy, decreased levels of greenhouse gas emissions, and enhanced environmental governance (Bao and Liu, 2022; Yang et al., 2020). GEA initiatives are instrumental in elevating public awareness and promoting sustainable behavior (Boudet et al., 2014). Furthermore, some studies have shown that there is a close relationship between government environmental policies and GTI. GEA can have a direct or indirect impact on the development of GTI. Governments have the ability to promote the development and widespread use of GTI by providing fiscal subsidies, tax incentives, and other supportive measures (Chang et al., 2022; Long and Liao, 2021). They can also influence market demand through the implementation of standardization and regulation (Chen and Zhang, 2010). Overall, GEA and GTI are two interconnected areas that are crucial for promoting environmental sustainability. The findings suggest that governments play a significant role in driving GTI, and GEA can stimulate innovation and adoption of green technologies.

According to the above analysis, we put forward hypothesis 1 in this research:

Hypothesis 1 (H1). GEA has a positive effect on GTI.

3.2. Influence mechanism of financing constraint channels

GEA plays a crucial role in promoting GTI. However, many factors hinder the development of GTI, and financing constraints are one of the most influential factors. Financing constraints can not only impede firms' ability to invest in GTI (Yu et al., 2021), but also arise from factors such as high-interest rates, limited access to credit, and inadequate financial resources (Lv et al., 2021). These constraints can reduce the ability to innovate and develop new technologies. One way that GEA can address financing constraints is through environmental policies such as fiscal subsidies, tax incentives, and other supportive measures. These measures can reduce the cost of capital for governments and create a favorable environment for GTI (Chang et al., 2022; Long and Liao, 2021). For example, fiscal subsidies for renewable energy can make it more attractive for firms to invest in solar panels or wind turbines. Similarly, tax incentives can reduce the tax burden on investment in GTI. Moreover, GEA can also encourage knowledge sharing and collaboration within industry clusters, which can further facilitate the development of new green technologies and overcome financing constraints (Wang et al., 2022).

According to the above analysis, we put forward hypothesis 2 in this research:

Hypothesis 2 (H2). GEA has the potential to indirectly support GTI by easing financing constraints.

3.3. Influence mechanism of industrial structure channels

In addition to financing constraints, the industrial structure is another key influence mechanism between GEA and GTI. GEA can motivate firms to adopt cleaner production processes and technologies, leading to the transformation of industrial structure towards cleaner and more sustainable industries. By implementing policies and regulations, providing financial incentives, and promoting innovation, governments can encourage firms to adopt more environmentally friendly technologies (Du et al., 2021). Governments can facilitate the transformation of industrial structure through policies and regulations that impose stricter environmental standards on firms. These policies and regulations can incentivize firms to adopt cleaner production processes and technologies, leading to a shift in the composition of industries towards those that are less polluting and more sustainable (Yu and Wang, 2021; Zhang et al., 2019). This process of industrial structure upgrading can create new opportunities for GTI, as firms seek to develop and apply new technologies to meet the stricter environmental standards. Moreover, industrial structure upgrading can also help to promote sustainable development and reduce environmental pollution (Wang and Wang, 2021).

According to the above analysis, we put forward hypothesis 3 in this research:

Hypothesis 3 (H3). GEA has a positive impact on GTI by promoting industrial structure upgrading.

4. Methodology and data

4.1. Empirical model

This paper tries to explore the impacts of GEA on GTI, and quantitatively tests the actual effect of GEA on GTI. As stated in the research conducted by Chen et al. (2022b), we consider the benchmark empirical model shown in Eq (1).

$$GTI_{it} = \alpha_0 + \alpha_1 GEA_{it} + \gamma' X_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (1)$$

where GTI_{it} denotes the green technology innovation of i city at t time, which includes three indicators: number of green invention patents (GTI_1), number of green utility model patents (GTI_2), and the total number of green technology innovation (GTI_3). GEA_{it} denotes the government environmental attention to i city at t time. Significantly, GEA_{it} is the summary of the previous government work at $t-1$ time and the prospect of government work at t time, which can effectively avoid the impact of reverse causality. Respectively, X_{it} is a vector of control variables. μ_i and ν_t denotes city fixed effect and time fixed effect, which can control unobservable variables at city and time trend. ε_{it} is the random error term.

According to the previous theoretical analysis, we intend to explore the influence mechanism of GEA on GTI. Mediating variables are considered to construct the following model shown in Eq (2).

$$MED_{it} = \alpha_0 + \alpha_1 GEA_{it} + \gamma' X_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (2)$$

where MED includes two mediating variables which are financing constraint and industrial structure. Other settings are consistent with the benchmark model.

4.2. Variable measurement

4.2.1. Dependent variable

Green innovation is one of the hot issues in economic research. The research perspectives of different works of literatures are diverse, resulting in a variety of indicators to measure green innovation in empirical research (García-Granero et al., 2018; Holger et al., 2017; Tseng et al., 2013; Wang and Yang, 2021; Zhao et al., 2021). Under the research background of this paper, we use patent applications to measure GTI, which can more accurately measure the output of innovation activities in terms of quantity and quality (Janger et al., 2017; Lin and Ma, 2022a; Rao et al., 2022). We obtain city-level patent data from China National Intellectual Property Administration (CNIPA) and match it with the "IPC Green Inventory" guideline published by World Intellectual Property Organization (WIPO). Following Du et al. (2019) and Lin and Ma (2022b), we use the total number of green technology innovation patents (GTI_1) to measure the GTI of the city. Additionally, according to the classification of green technology patents, we divided green patents into the number of green invention patents (GTI_2) and the number of green utility model patents (GTI_3). Invention patents and utility model patents can represent high-quality innovation (Hu et al., 2020; Lin and Ma, 2022a). Meanwhile, we adopt a method used by Tan et al. (2023) and use the natural logarithm of the number of green patent applications plus one to measure corporate green innovation. This approach can help us address the issue of skewed data and improve the consistency and reliability of our analysis. We can transform the data into a more normal distribution, which can be beneficial for statistical analysis. Furthermore, we use authorizations of green technology innovation patents to replace dependent variables for the robustness test in Section 5, which can eliminate the impact of other unobservable factors (Ma et al., 2021; Wang et al., 2019).

Fig. 1 shows the number of green technology innovation patents across Chinese cities in 2010 and 2020. We can find that the development of GTI has made significant progress in recent years, and this progress can be seen in various areas such as renewable energy, sustainable transportation, and

eco-friendly materials. Additionally, the development of GTI presents significant regional heterogeneity, especially between southeastern and northwestern regions.

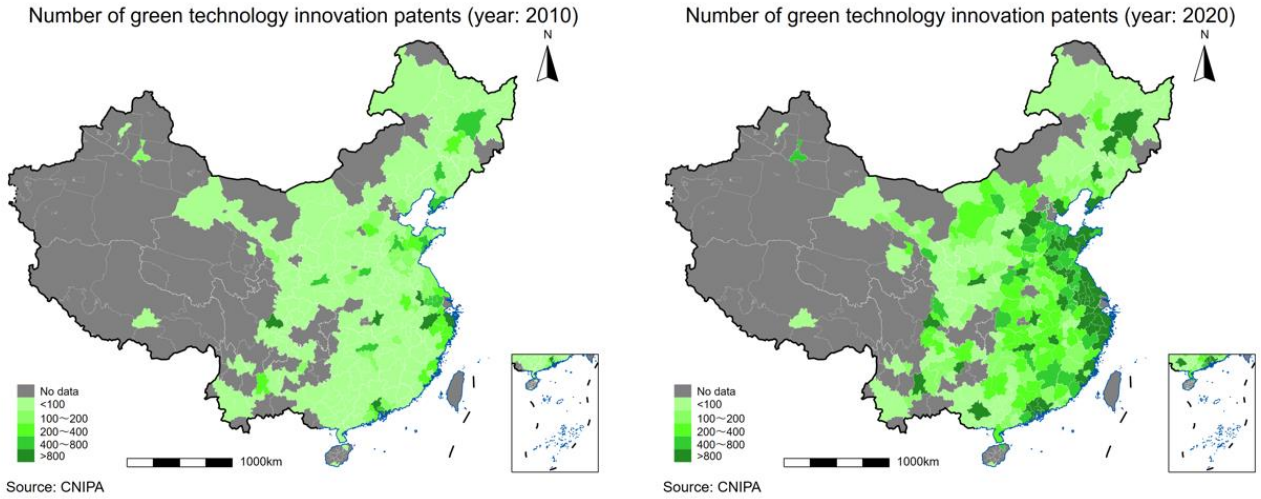

Fig. 1. Number of green technology innovation patents in 2010 and 2020.

4.2.2. Independent variable

GEA is the key independent variable. Following Tian et al. (2022) and Chen et al. (2022a), we use textual analysis to construct GEA. This method was used in informatics, but now it can be used in social sciences to measure the attention allocated by decision-makers to environmental issues (Huang et al., 2022; Pauwels, 2011; Quinn et al., 2010). In general, to measure the extent of the government's focus on environmental matters, we extract the frequency of environmental keywords contained within official government work reports. The frequency of relevant keywords serves as an indicator of the government's prioritization of environmental attention. Higher frequencies of these keywords are suggestive of an increased level of attention paid by the governments to these issues. Specifically, In the first step, we collect 297 government work reports at the city level from 2007 to 2020, which are obtained from official government websites. In the second step, we extract keywords related to environmental protection from various environmental policy reports and documents (Shen et al., 2020). In the third step, we utilize the natural logarithm of environmental protection frequency plus one to quantify GEA. Furthermore, considering the potential impact of text length on our analysis, we use the proportion of environmental protection frequency in the full government work report to replace the independent variable for the robustness test in Section 5 (Bao and Liu, 2022; Jin, 2016).

Fig. 2 shows the frequency of keywords related to environmental protection in 2010 and 2020. We can find that local governments in China have paid deep attention to environmental issues and emphasized the importance of environmental protection in government work reports. Moreover, GEA exhibits regional heterogeneity over time.

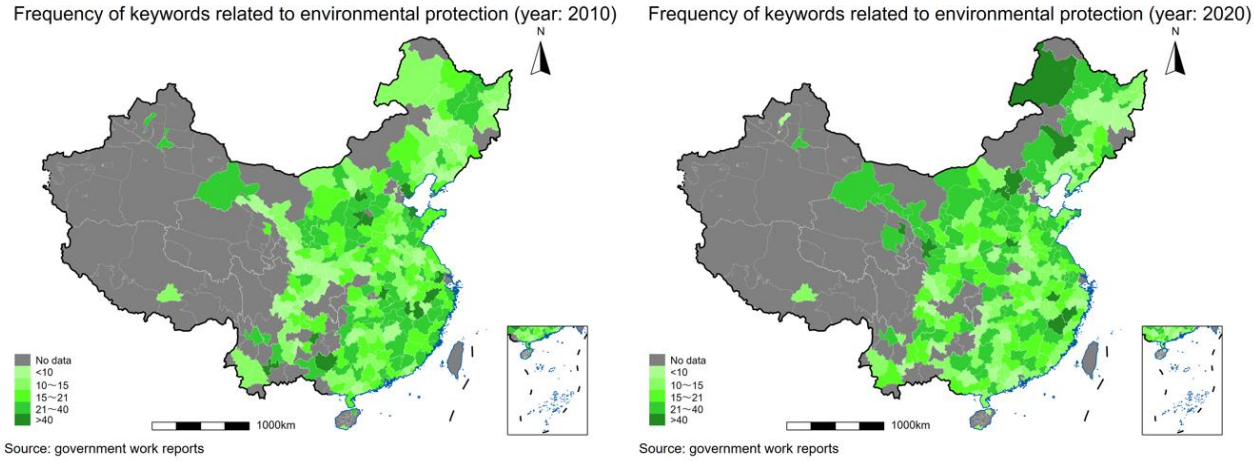

Fig. 2. Frequency of keywords related to environmental protection in 2010 and 2020.

4.2.3. Control variables

For control variables, the empirical model includes several important control variables to mitigate the impact of various driving factors on GTI.

Economic development level (lnGDP). Technology innovation is an important determinant of economic growth (Schumpeter, 1912; Solow, 1956); on the other hand, the realization of economic growth provides a necessary material guarantee for technological progress (Aghion et al., 2015; Romer, 1990). Besides, economic growth has a positive impact on environmental awareness, which has a positive effect on GTI (Beckerman, 1992; Li et al., 2022; Van den Bergh, 2011). Following Stevenson and Wolfers (2013), lnGDP is measured by the logarithm of per-capita GDP.

Financial R&D expenditure (RD). Financial R&D expenditure reflects the support of local governments for technology innovation. R&D subsidies help alleviate the financial risk of enterprise R&D activities and lead to GTI (Howell, 2017; Le and Jaffe, 2016). Following Chen et al. (2021), RD is measured by the ratio of R&D expenditure to GDP.

Government fiscal support (GOV). Moderate government intervention is important for effective factor allocation and technology innovation vitality (Gao, 2015; Wang, 2018). Following Lin and Ma (2022a). GOV is measured by the ratio of fiscal budget and expenditure to GDP.

Foreign direct investment (FDI). The relationship between FDI and technology innovation has been widely studied. As an important carrier of technology transfer, FDI helps to realize technology transfer through technology spillovers (Song and Han, 2022; Xu et al., 2021). FDI is measured by the ratio of foreign direct investment to GDP.

Population (lnPOP). As the endogenous growth model, a larger population simulates technology innovation (Kremer, 1993). From empirical analysis, population growth may have a negative impact on technology innovation (Coccia, 2014). POP is measured by the logarithm of the city's population.

Proportion of secondary industry (SIR). The secondary industry has a high proportion of carbon emissions and a fast growth rate, which has a closely connection to GTI (Hao et al., 2020; Wang et al., 2022). SIR is measured by the ratio of secondary industries to GDP.

Resource endowment (RES). The development of cities depends on resource-based industries. Resource-based cities face greater pressure of green transformation than non-resource-based cities, so

they have a more urgent demand for GTI (Wang and Li, 2020; Wang and Ma, 2022). RES is measured by the proportion of mining employment in the total local employment.

Fiscal expenditure on education (EDU). The development level of education directly affects the cultivation of innovative talents and then affect the efficiency of regional innovation (Wu and Liu, 2021). EDU is measured by the ratio of fiscal expenditure on education to GDP.

Human capital (lnHC). High-level human capital can affect technology innovation through the knowledge spillover effect (Engelbrecht, 2002; Hu, 2021). lnHC is measured by the logarithm of workers' average wage.

4.2.4. Mediating variable

Financing constraints (FIN). A good financing environment can provide favorable conditions for the development of technology innovation, which can moderate the relationship between GEA and GTI (Khan et al., 2021). Financing constraints are measured by two indicators: FIN_1 is measured by the ratio of deposits from financial institutions to GDP, FIN_2 is measured by the logarithm of per-capita deposits from financial institutions. The higher FIN_1 and FIN_2, the smaller financing constraints.

Industrial structure (IS). The upgrading of industrial structure plays an important role in promoting green innovation performance (Yang et al., 2022). Industrial structure is measured by two indicators. Following Wang et al. (2021), IS_1 is measured by the indexes of the industrial structure advancement. Following Du et al. (2021), IS_2 is measured by the ratio of tertiary industry to secondary industry. The higher IS_1 and IS_2, the greater upgrading of industrial structure.

4.3. Data

This paper collects unbalanced city-level panel data from 2004 to 2020 in the main research sample. The raw data on GEA is collected from official government work reports. The green patent data is collected from China National Intellectual Property Administration (CNIPA). The data of control variables are collected from China City Statistical Yearbook and CEIC database. The statistical description of variables is shown in **Table 1**.

Table 1

Descriptive statistics.

Variable	Definition	Obs	Mean	Std. Dev.	Min	Max
GTI_1	Total number of green technology innovation patents	5,525	4.070	1.884	0.693	10.032
GTI_2	Number of green invention patents	5,525	3.146	1.918	0	9.421
GTI_3	Number of green utility model patents	5,525	3.570	1.814	0	9.294
GEA	Government environmental attention	5,776	2.780	0.651	0	4.543
lnGDP	Per-capita GDP	5,387	0.864	0.955	-1.810	3.975
RD	The ratio of R&D expenditure to GDP	5,129	0.201	0.243	0	6.310
GOV	The ratio of fiscal budget and expenditure to GDP	5,664	16.681	11.492	2.790	234.876
FDI	The ratio of foreign direct investment to GDP	5,135	2.123	2.662	0	47.627
lnPOP	City's population	5,430	5.847	0.720	-3.219	8.136
SIR	The ratio of secondary industries to GDP	5,421	46.715	11.425	10.680	90.970
RES	The proportion of mining employment	4,585	5.808	9.430	0	58.127
EDU	The ratio of fiscal expenditure on education to GDP	5,131	3.075	1.830	0.122	18.547
lnHC	Average wage	5,679	1.105	0.739	-6.927	2.918

5. Empirical results and discussion

The analysis will complete soon

6. Conclusions and policy implications

6.1. Conclusions

Green innovation activities have gained significant attention from governments worldwide due to the escalating global climate change and environmental pollution. As a result, governments are increasingly prioritizing environmental issues, which in turn, has accelerated the growth and development of green innovation activities. Using panel data of city-level panel data from 2004 to 2020 in China, we investigate the relationship between GEA and GTI, as well as the heterogeneity effect and influencing mechanism. According to theoretical analysis and empirical tests, we examine how, and through what influencing mechanisms, GEA affects the development and adoption of GTI. The conclusions are as follows:

Firstly, GEA plays a beneficial role in promoting GTI, and the results are robust after considering endogeneity and further robustness test. Secondly, the impact of GEA on GTI is heterogeneous. Relatively speaking, for cities in coastal, high-level economic development, and high-level agglomeration areas, the positive influence of GEA on GTI is more obvious. Thirdly, the mechanism test shows that GEA has the potential to indirectly support GTI by easing financing constraints and promoting industrial structure upgrading. Overall, our study highlights the importance of government attention to environmental issues in promoting GTI. We hope that our findings contribute to a better understanding of the relationship between GEA and GTI, and ultimately provide policy enlightenment for achieving sustainable low-carbon development.

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