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Resource Radiation Effect: The Impact of Technological Innovation Output on Environmental Governance During the Dual Dynamic Process

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Abstract: The ecological environmental technology innovation system plays a crucial role in the development of Chinese ecological civilization. This study researches the effect of the technology innovation output (TIO) on environmental governance, extending this notion to ecological environmental technology innovation atmosphere (EETIA). The dual dynamic processes, the resource change and the innovation influence processes have imported. Two processes have the counity in time, which put this effect research into the dynamic change. A regional radiation effect model, employed to describe resource transmission between regions, is applied in completing the first process. The analysis reveals TIO exerts a current impact with a negative linear influence on EETIA in the short time. Moving to the second process, which addresses long-term impacts, it is found that TIO influence exhibits a positive impact on EETIA. Grouping regions and policy simulations justify that accelerating the first process will facilitate a quicker realization of the second process.

Keywords: Dual Dynamic Process; Regional Radiation Effect Model; Policy Simulations; Regional Grouping; Government Intervention.

1. Introduction

In the context of promoting carbon peaking and carbon neutrality, Xi Jinping, the Chinese president, pointed out that "to break through the bottleneck of self-development and solve deep-seated contradictions and problems, the fundamental way out lies in innovation, and the key is to rely on scientific and technological strength." Strengthening core technologies is a significant necessity for tackling the "neck-breaking" essential issues in the domain of the ecological environment and also the sole means to improve environmental governance. Technical innovation output is constantly tied to environmental governance. Wang (2020) [1]asserted that there is an inescapable relationship between technological innovation and the environment, and environmental legislation has to some degree encouraged innovative production. Liu (2018) [2]assessed the effect of environmental regulation on green innovation in high-polluting industries. Li (2023) [3]analyzed the impact of environmental regulation on the high-quality development of enterprises and its implementation strategy. It may be observed that the objective of environmental regulation is to safeguard the environment and restrain firms and people, who boost technological output to a certain extent. The most research on environmental and innovation drew attention to the relevance of environmental regulation and technological innovation output. Environmental regulation is actually building an atmosphere of ecological environment preservation in society, but this only concentrates on the environment and cuts off the link with innovation. Xi Jinping, the Chinese president, pointed out that it is necessary to establish an ecological and environmental science and technology innovation system by connecting technical innovation to environmental management. The latest study on the relationship between environment and technological innovation mainly focuses on the textile industry, industry (Qiu 2023)[4], and other business sectors. By expediting the transfer of energy production modes, technological innovation gives tremendous potential for the low-carbon development of conventional energy firms (Liang et al., 2022)[5]. Ma (2021)[6] argued that a strong positive link existed between technical innovation and environmental regulation in rising marine industries. However, these may cause the range of technological innovation output (TIO) to be confined to the basic output without considering the dynamic change in resources and continued influence and environmental governance is only represented by environmental regulation. Omri (2020) [7]analyzes the varying roles of technological innovation in reaching sustainable development in different types of countries. Ahmad (2021)[8] adds economic investment aspects to ecological protection. However, these studies may cause the range of technological innovation output (TIO) to be confined to the basic output without considering the dynamic change in resources and continued influence, and environmental governance is only represented by environmental regulation.

Base on the above reference, this article describes TIO in the perspective of resources endowment and employs the ecological environment technological innovation atmosphere (EETIA) index as a description of environmental governance. It is important to choose a suitable carrier to research the relationship of TIO and environmental governance. Cao (2023)[9] proposes that there is a U-shaped link between environment and innovation under the carrier of industry. Tjornbo (2022)[10] underlines the relevance of the social innovation ecosystem in universities. For the system of scientific and technological innovation, colleges and universities play the role in training talents, carrying out scientific research, and fostering technological innovation. Therefore, this essay chooses the university as the carrier to research the effect of TIO on EETIA. Zhang (2022) [11]proposes the relationship between green investment, natural resources, green technological innovation, and economic growth, which incorporates other elements such as natural resources, funds and etc. It demonstrates that other multiple elements need to be considered in the process of environmental governance. So this study undertakes research on the aspect of resource endowment. Resource endowment (Su et al., 2023)[12] mainly refers to human resources, financial resources, natural resource reserves, etc. Li (2023)[3] studies the impact of industrial structure and resource endowment on green innovation efficiency. Shen (2022)[13] argues that environmental limits and resource endowment are both key aspects effecting technological innovation efficiency under the "dual carbon" objective constraint. Yang (2023)[14] highlights regional inequalities in the production performance of green industries from the perspective of resource endowment. Resource endowment plays a crucial function in technological innovation and green environmental protection.

This research studies the effect of technological innovation output (TIO) in university on establishing an ecological technological innovation atmosphere (EETIA) from the position of resource endowment, including people resources, technology resources, capital resources, and a prospective growth perspective. Yan contends that the ecological environment has a one-way impact on technological innovation from a geographical division standpoint. But the influence of TIO on EETIA can't be a simple one-way impact. Fig. 1 shows Four contributions are highlighted in these articles.

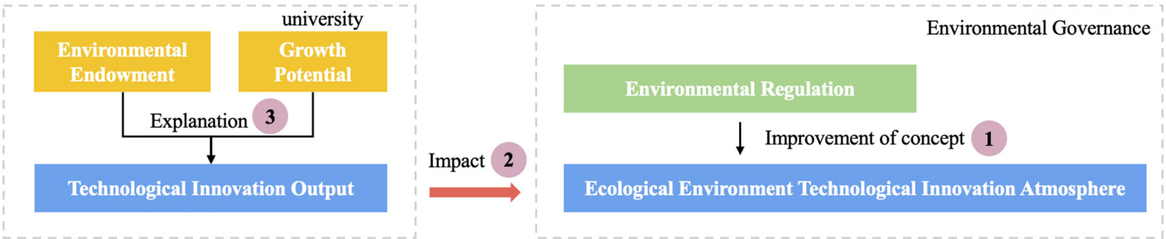

Fig 1. Idea improvement diagram

Firstly, it enriches the concept of environmental governance by rasing the latest concept: the Ecological Environment Technology Innovation Atmosphere (EETIA), which adds the economic insights.

Secondly, define the independent core variable: Technological Innovation Output (TIO) from the perspective of resource endowment and potential growth.

Thirdly, putting the research about the effect of TIO on EETIA into the dual dynamic processes: the dynamic processes of resources and innovation output. Two continuous processes help to research the varations of EETIA.

Fourthly, import the regional radiation effect model to complete the first process helping verify the importance of regions and government intervation.

2. Literature Review

2.1. The Relationship of TIO and EETIA

In recent years, China's research on technological innovation output and environmental governance has steadily grown. Ziegler (2009)[15] explored the causal connection between technological innovation and environmental management systems. Guo (2017)[16] evaluated the interaction implications of environmental regulation and technological innovation on regional green development performance. Debnath (2015)[17]introduced the notion of environmental regulation, and environmental regulation becomes a restraint or incentive for innovation. Makkonen (2018)[18] stresses the significance of environmental regulations as a driving element for the development of technological innovation systems concentrating on environmental innovation. Environmental control has been the main subject in the green research sector. However, the idea of environmental governance has to be broadened to integrate the new age. Establishing an ecological environment technology innovation system is vital to attaining a win-win scenario between economic development and environmental governance. Green (2002)[19] analyzes environmental components such as social innovation in lifestyle and culture, which underlines the relevance of innovation acting on the environment. Souitaris (2002)[20] highlighted technical innovation from external contexts and current capabilities to compare two types of organizations. Ohyama (2008)[21] indicates that the establishment of environmental policy is connected to technology and economics. The description of the environment evolves into various components of the environment, such as existing innovation elements, economic elements, and green environmental variables. Sabadie (2014)[22] introduces technical innovation, human capital, and social change for sustainable development.

This study, considering economic development, contemporary green scenarios, and environmental regulation at the same time, deepens the idea of environmental governance as an atmosphere of ecological environment technology innovation, dubbed the ecological environment technology innovation atmosphere (EETIA). This article imports EETIA, the dependent variable, focusing on the function of technological innovation output on the EETIA, which shows whether the technological innovation output is important to a social aggregation combining ecology, economy, and social progress, not solely researching one of the above elements.

2.2. The Research Method about TIO and EETIA

Fischer (2003)[23] imports policy tool variables to govern diverse scenarios of technological innovation. Huber (2008)[24] examines technological innovation through life cycle and chain factors. Yabar (2013)[25] utilizes technical kinds and corresponding patent applications to characterize technological innovation output. The percentage of R&D investment is employed in structuring technological innovation (Ma et al., 2021)[26]. Liao (2023)[27] utilizes the Internet as a technological innovation and concludes that environmental pollution may be reduced by technological innovation. Different from the prior articles employing numerous common indices or even one index to characterize technological innovation, this article describes technological innovation from the perspectives of resource endowments and growth potential. By integrating these two aspects, we acquire a more holistic perspective of technological progress, not depending solely on a restricted number of indices, allowing us to deliver a more thorough study.

Bretschger (2005)[28] assesses the compatibility of economic growth and natural resource utilization. Diametrically contrary to Debnath (2015)[17], who proposes environmental regulation becomes a restraint or incentive for technological innovation by utilizing the SWTO approach to undertake qualitative study. Jin (2019)[29] constructed a varied technological innovation system and investigated green R&D input as an independent variable. He separated the territory into three parts: the east, center, and west areas to evaluate various functions of technological innovation in dissimilar areas. Wang (2020)[1] proposed that technological innovation and environmental pollution developed a nonlinear link when utilizing FDI amount and FDI quality as threshold factors. Gao (2023)[30] Different environmental advances will impact environmental quality in BRICS countries. The connection between environmental regulation and technological innovation is not a simple linear relationship; according to Xin (2021)[31], there is a nonlinear relationship between environmental regulation and technological innovation. Zhang (2022)[32] highlighted the dynamic interaction between green investment and ecological footprint, utilizing the NARDL technique to explore the short-run and long-run connections between them. Most papers limited ecological management to environmental pollution scenarios, environmental control, and so forth. Because of this, a lot of conflicting findings may always be obtained when conducting both qualitative and quantitative analysis. By enhancing the conceptions of ecological management and technological innovation as fully as possible, this paper offered causal research on new notions in the contemporary environment.

Linear spatial econometrics was used to recognize that the advent of technology and imitative innovation had substantially boosted environmental performance (Ai et al., 2015[33]). Irandoust (2016)[34] designed a vector autoregression (VAR) model to quantify the quantitative association between renewable energy use, technological innovation, economic growth, and CO2 emissions. Pan (2019)[35] applies the directed acyclic graph (DAG) and structural vector autoregression (SVAR) to investigate the internal dynamic interaction among environmental regulation, technological innovation, and energy efficiency. Ahmad (2023)[36] employed a novel panel method of moments quantile regression, revealing that economic openness contributed greatly to a decrease in environmental quality by choosing numerous sample countries. Bai (2024)[37] indicates that green finance policy has a stronger beneficial effect on green innovation by employing the DID model. Based on the empirical model mixed with province divisions Jin (2019)[29] presented, this article employs this technique to increase the empirical model's correctness, and more accurate results may be achieved in order to give applicable policy proposals.

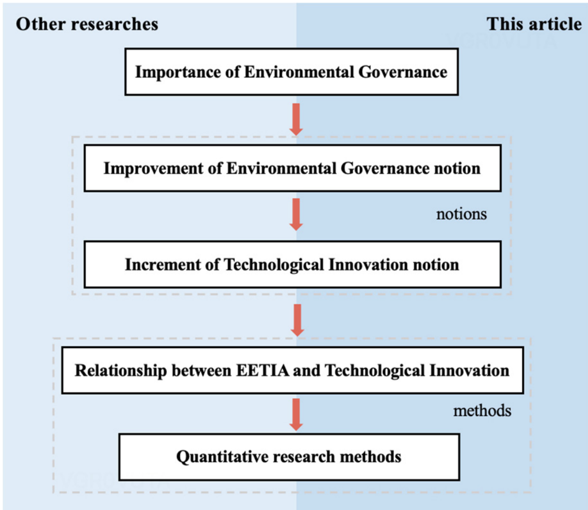

Fig 2. Research pathways

Summarizing the benefits and limits stated above, this article primarily provides some contributions in Fig.2, which shows these aspects, compared with other researches, are improved in this articles. Further, this paper offers an enhanced physical model: a regional radiation effect model that describes the transmission of resources between regions.

3. Methodology

3.1. Theoretical Framework

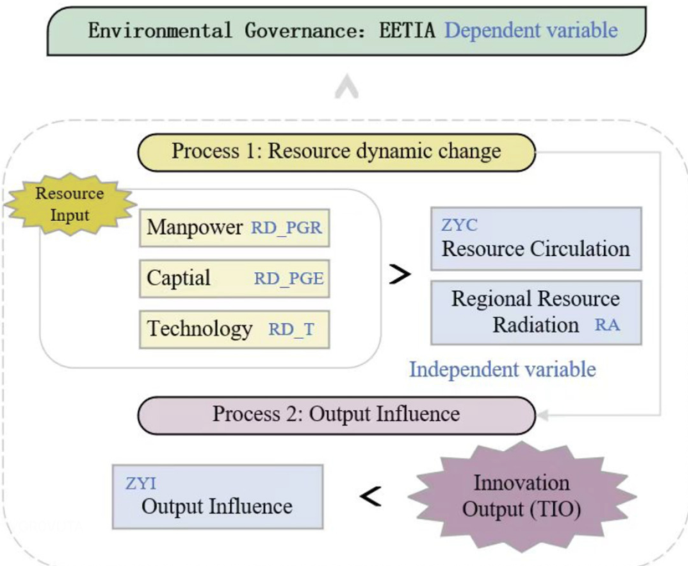

Fig 3. The framework of two dynamic processes

In this research, the impact of TIO on EETIA is explored. The dual dynamic process from the perspective of resource endowment is imported, extending to the resource change of short-term process and output influence of long-term process. Resource input, resource circulation (Hu et al., 2023)[38] and regional resource radiation makes up the short-term process. Technology innovation output influence process is the long-term process. Integrating the study about the influence of the core variable TIO and the control variables on EETIA within the framework of dual dynamic processes. Fig. 3 shows the framework of dual dynamic processes.

TIO represents the current impact of technology innovation output on EETIA, which exists in the short-term process. Generally, TIO may generate pressure to the environmental carrying capacity and hinder environmental governance. Thus, the following hypothesis is proposed:

H1: The TIO generates pressure to the environmental carrying capacity and has a negative effect on EETIA in the short term.

The short-term process involves the consumption, circulation, and regional radiation of resources, which includes not just TIO but also three control variables that correspond to the changes in these resources. The resource input comprises human resources, financial resources, and project resources, seen from the standpoint of resource endowment. Various categories of resources operate on EETIA in distinct ways. Thus, the following hypotheses are proposed:

H2a: The human resources accelerate the process of environmental resource consumption and have a negative effect on EETIA in the short term.

H2b: The financial resources expand the development of environmentally friendly materials and have a positive effect on EETIA in the short term.

H2c: The project resources have a corresponding effect on EETIA according to the content of the project in the short term.

Resource circulation refers to the interchange of scientific and technical information and methodologies among researchers. In the short term, it may enhance researchers' capacity for technological innovation but have little impact on environmental quality. Therefore, the following hypothesis is put forward:

H3: Resource circulation has an effect on EETIA in the short term.

Regional resources radiation refers to the distribution of resources over different locations, taking into account their transitivity and liquidity. This distribution varies based on the geographical distance between regions. The transmission impact is pronounced in the nearby regions, whereas it is diminished in the far locations. This radiation effect will enhance the ability for scientific and technical innovation in the short term, but it is not favorable for the immediate progress of the environment. Therefore, the following hypothesis is put forward:

H4: Regional resource radiation accelerates technological innovation while putting strain on the environment by transporting resources across areas, which has a short-term negative impact on EETIA.

In general, technological advancement will have a detrimental impact on the environment in the near term, as supported by relevant references. The second process signifies the long-term effects of technological innovation outcomes. The module transforms from TIO to TIO influence. Eventually, the output of technological innovation will optimize the structure of resource use and environmental governance. Therefore, the following hypothesis is put forward:

H5: the influence of technological innovation output will optimize energy structure and improve the ability to green environment, which has a positive impact on EETIA in the long term.

3.2. Data Source and Processing

Table 1. The whole index information

Index	Data	source
EETIA	Greenness Index	China City Green Competitiveness Index Report
	Growth rate of graduate student enrollment	China Education Statistical Yearbook
	Growth rate of the number of published scientific papers	Statistics and Analysis of Chinese Scientific and Technological Papers
	Growth rate of the number of technological works published	Statistics and Analysis of Chinese Scientific and Technological Papers
	Growth rate of effective invention patents	Statistics and Analysis of Chinese Scientific and Technological Papers
TIO	The number of graduate students enrolled in the year	China Education Statistical Yearbook
	Publication of scientific papers	Statistics and Analysis of Chinese Scientific and Technological Papers
	Publication of scientific and technical works	Statistics and Analysis of Chinese Scientific and Technological Papers
	Valid invention patents	Statistics and Analysis of Chinese Scientific and Technological Papers
RD_PGR	Growth rate of R&D personnel	Statistical Yearbook
RD_EGR	Growth rate of internal expenditure of R&D funds	Statistical Yearbook
RD_T	The number of papers exchanged per 100 attendees	Statistical Yearbook
ZYC	Number of papers exchanged per 100 attendees	Statistical Yearbook
ZYI	SCI, EI and CPCI-S accounted for the proportion of papers from higher education institutions in the region	Statistics and Analysis of Chinese Scientific and Technological Papers

To analyze the impact of technological innovation output (TIO) on the ecological environment technology innovation atmosphere (EETIA). This article has chosen TIO as the primary independent variable and EETIA as the dependent variable. Fundamental and growth control variables are chosen relying on resources endowment from the viewpoints of resource input, resource circulation, and resource effect. Among them, the resource input includes: the growth rate of R&D, people (RD_PGR), the growth rate of internal spending of R&D money (RD_EGR), and the number of R&D projects (RD_T); The number of papers exchanged per 100 attendees (ZYC), with people as the carriers, is used to represent resource circulation. The regional proportion of papers from colleges and universities included in SCI, EI, and CPCI-S (ZYI), relevant to regions and long-term influence, is used to represent resource impact. The complete index detail information is in Table 1.

4. Model Specification

4.1. The Fundamental Model of EETIA

In order to make the findings more interpretive, this research eliminates utilizing logarithmic change, but uses the original variable to analyze the link between the dependent variable and the independent variable. Based on this precondition, this research raises four models: the mixed OLS model, the random effects model, the fixed effects model, and the time and individual fixed effects model. By changing feature data into a matrix to evaluate various models, the research verifies the main model: Time and Individual Fixed Effects (Ostadzad, 2022)[39] Model and the math formula is as follows:

$$EETIA_{it} = \beta_0 + \beta_1 TIO_{it} + \beta_2 RD_{PGR}{}_{it} + \beta_3 RD_{EGR}{}_{it} + \beta_4 RD_{T}{}_{it} + \beta_5 ZYC_{it} + \beta_6 ZYI_{it} + u_i + \gamma_t + e_{it} \quad (1)$$

where u_i represents the individual fixed effect, γ_t represents the time fixed effect, and e_{it} represents the random error term.

The theoretical model shows there is a linear link between EETIA and TIO. Considering continuity of resource changes, Eq. (1) represents TIO's function on EETIA during the dual process (Sun et al., 2023)[40]. The regional radiation effect model is imported in the first process, with resources emitting as particles from one area to the other. This work develops a resource-pulling hypothesis, which indicates that resource-rich locations have a pull-on impact on resource-scarce areas.

In this research, the gravitation model (Maurya et al., 2023)[41] is upgraded to the regional radiation effect model innovatively. The influence of resource pull power between regions is regarded as the flow of resource particles between regions, and the resource particles are mainly given meaning from the perspective of resource endowment (Zhao, 2023)[42] referring to knowledge elements, talent elements, economic factors, etc. the regional radiation effect model is as follows:

Three assumptions are made about radiant energy for a single resource particle: particle emission assumption, regional threshold comparison assumption, and particle absorption assumption. Firstly, particle emission assumption is that a particle y is emitting from region i has an absorption threshold $z_x^{(i)}$ and the largest absorption threshold ensuring this particle cannot be absorbed by other regions. In this paper, $z_x^{(i)}$ is defined as the maximum value extracted from the arbitrary distribution $p(z)$ in m_i times. Secondly, a higher threshold value means the region having high density particles. when $n+1$ extraction procedures are equal to n extractions and one extraction, the chance of being extracted a higher threshold value is raised a lot in the region of high density particles. Thirdly, the particle absorption assumption is that when meeting the conditions: $z_x^{(j)} > z_x^{(i)}$ and region j is nearest to region i, particle y is absorbed from region i to region j.

It is feasible to compute the flow of all resource particles by investigating the flow mechanism of a single resource particle:

Suppose $P(1|m_i, s_{ij}, n_j)$ represents the probability of emitting a resource particle from region i to region j (see Fig.4). z is the radiation energy effect in the resource particles, assuming that the resource particles are extracted from the arbitrary distribution of $p(z)$, the whole radiation system is divided into three populations, namely the starting population, the intermediate population, and the end population, and the radiation particles of these three populations are extracted m_i, s_{ij}, n_j from $p(z)$ respectively. The particles extracted from the starting population y_1 were: $y_{11}, y_{12}, y_{13} \cdots y_{1m_i}$; The particles extracted from the intermediate population y_2 were: $y_{21}, y_{22}, y_{23} \cdots y_{2s_{ij}}$; The particles extracted from the y_3 of the end population are: $y_{31}, y_{32}, y_{33} \cdots y_{3n_j}$.

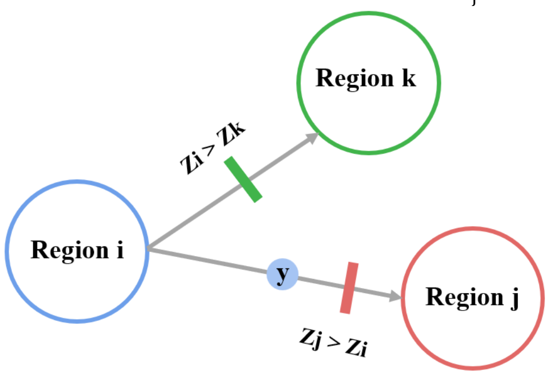

Fig 4. The principle of regional particle pulling

In the whole region s_{ij}, one particle y is emitted from region $i(m_i)$ to region $j(n_j)$. So the particle y is integrated on $[0, +\infty]$ on the energy effect z, which is the probability of particle y absorbed by region j, denoted as $P(1|m_i, s_{ij}, n_j)$. In this process (see Fig. 4), the energy effect z_i of particle y should be greater than the absorption threshold z_k of the intermediate population y_2, and less than the absorption threshold z_j of the end population y_3, So that the resource potential particles are absorbed by the end population.

$$P(1|m_i, s_{ij}, n_j) = \int_0^{+\infty} f_{mi}(y_{1(m_i)} = z) dz \, P_{s_{ij}}\left(y_{2(s_{ij})} < z\right) P_{n_j}\left(y_{3(n_j)} > z\right) \quad (2)$$

$$f_{mi}(y_{1(m_i)} = z) = \lim_{\Delta z \to 0} \frac{P_{m_i}(y_{1(m_i)} \le z) - P_{mi}(y_{1(m_i)} < z)}{\Delta Z} = \frac{d\left(P_{mi}(y_{1(m_i)} < z)\right)}{dz} = \frac{d\left(P_{m_i}(y_{11}<z, y_{12}<z \cdots y_{1m_i}<z)\right)}{dz} = \frac{(P(<Z)^{m_i})}{dz} \_ \frac{m_i P(<Z)^{m_i - 1} dp(<z)}{dz} \quad (3)$$

$$P_{s_{ij}}\left(y_{2(s_{ij})} < z\right) = P_{s_{ij}}\left(y_{21} < z, y_{22} < z, \cdots, y_{2s_{ij}} < z\right) = P(< Z)^{s_{ij}} \quad (4)$$

$$P_{n_j}\left(y_{3(n_j)} > z\right) = 1 - P_{n_j}\left(y_{31} < z, y_{32} < z \cdots, y_{3n_j} < z\right) = 1 - P(< Z)^{n_j} \quad (5)$$

Substituting Eq. 3-5 into Eq. 2 yields:

$$P(1|m_i, s_{ij}, n_j) = \int_0^{+\infty} m_i\left(P(< Z)^{m_i+s_{ij}-1} - P(< Z)^{m_i+n_j+s_{ij}-1}\right)dp(< z) \quad (6)$$
$$= m_i\left(\frac{1}{m_i + s_{ij}} - \frac{1}{m_i + n_j + s_{ij}}\right)$$
$$= \frac{m_i n_j}{(m_i + s_{ij})(m_i + n_j + s_{ij})}$$

Suppose a sequence of resource particles $(T_{i1}, T_{i2}, \ldots, T_{it})$, and multinomial distribution can be used to describe its distribution:

$$P(T_{i1}, T_{i2}, \ldots, T_{it}) = \frac{T_i!}{T_{i1}!\,T_{i2}!\ldots T_{it}!} P_{i1}^{T_{i1}} P_{i2}^{T_{i2}} \ldots P_{it}^{T_{it}} \quad (7)$$

Calculate the probability that the T_{ij} element, emitted from region $i(m_i)$ to region $j(n_j)$,is absorbed exactly:

$$P(T_{ij}|m_i, n_j) = \frac{T_{ij}!}{T_{ij}!\,(T_i - T_{ij})!} P_{ij}^{T_{ij}}(1 - P_{ij})^{T_i - T_{ij}} \quad (8)$$

$$\langle T_{ij}\rangle = E\left(P(T_{ij}|m_i, n_j)\right) = T_i \frac{m_i n_j}{(m_i + s_{ij})(m_i + n_j + s_{ij})} \quad (9)$$

In this paper, defining the $\langle T_{ij}\rangle$ function is a regional radiative pulling force function F_{ij}, and the total radiative influence of the function is composed of two parts: the radiation capacity P_{ij} and the radiation intensity T_i:

$$F_{ij} = \langle T_{ij}\rangle = T_i P_{ij} \quad (10)$$

$$P_{ij} = \frac{m_i n_j}{(m_i + s_{ij})(m_i + n_j + s_{ij})} \quad (11)$$

$$s_{ij} = |m_i - n_j| \quad (12)$$

Where T_i represents the government support degree, m_i and n_j represent the resource status of region i and region j respectively, and use TIO features combined with the Gray Entropy weight method to calculate the resource status score of each region and substitute it into m_i and n_j for calculating P_{ij}. Finally, F_{ij} represents the driving force of region i to region j and the regional radiation effect is calculated by the arithmetic mean of F_{ij}.

$$\overline{F_i} = \frac{\sum_{j=1}^{31} F_{ij}}{n}, j \neq i \quad (13)$$

To determine the regional radiation effect of each province to other province, this study first computes the regional radiation effect to all other provinces, then averages the values to obtain the mean radiation score of each province (see Eq . 13), which is denoted as RA, and the mean radiation scores of all provinces are in the **Appendix.**

Fig 5. heat-map of region's radiation capacity

Fig. 5 depicts how the region's radiation capacity extends outward from the center. The provinces that are geographically remote and have few neighboring cities, like Xinjiang and Tibet, have a weaker radiation effect, while the regions that are geographically located in the center and have more neighboring cities, like Henan, Shandong, Anhui, etc., have a stronger radiation effect. This illustrates that the regional radiation effect is really a geographical spreading effect, which is added to the first process helping to expand the model in the geographical viewpoint. The radiation ability (RA) is incorporated in the basic model and the model formula is adjusted as follows:

$$EETIA_{it} = \beta_0 + \beta_1 TIO_{it} + \beta_2 RD_{PGR_{it}} + \beta_3 RD_{EGR_{it}} + \beta_4 RD_{T_{it}} + \beta_5 ZYC_{it} + \beta_6 ZYI_{it} + \beta_7 RA_{it} + u_i + \gamma_t + e_{it} \quad (14)$$

The regional transmission relies on altering regional elements, which may be controlled by government intervention. An examination of the regional effects of radiation will be conducted to provide recommendations on this issue. In order to do additional studies on the link between EETIA and TIO, the area will be grouped, and policy intervention will be stimulated.

5. Conclusion

5.1. Results on the Relationship of EETIA and TIO

Before showing the EETIA and TIO relationship results, the description and correlation of variables will be discussed in this section. The first part is the description of variables (table2)

Table 2. The description of variables

variable	N	mean	p50	sd	min	max
EETIA	120	0.303	0.280	0.122	0.0950	0.680
TIO	120	1.600	1.605	0.373	0.936	2.591
RD_PGR	120	0.100	0.0810	0.122	-0.218	0.632
RD_EGR	120	0.188	0.165	0.224	-0.359	1.111
RD_T	120	34350	27388	25411	1114	115571
ZYC	120	52.89	52.41	18.86	6.450	109.6
ZYI	120	0.845	0.873	0.112	0.385	0.973
RA	120	0.395	0.407	0.104	0.0580	0.538

Table 2 indicates that while RD_T and ZYC are more dispersive, the majority of variables are densely distributed. The second part is the correlation of variables (Fig. 6). Light blue implies a weaker correlation between variables, whereas dark blue denotes a tighter association.

	EETIA	TIO	RD_PGR	RD_EGR	RD_T	ZYC	ZYI	RA
EETIA	1	0.726	0.112	-0.031	0.808	0.185	0.129	0.113
TIO	0.726	1	0.227	0.27	0.807	-0.152	0.176	0.116
RD_PGR	0.112	0.227	1	0.163	0.245	0.085	0.138	0.167
RD_EGR	-0.031	0.27	0.163	1	0.005	-0.104	-0.001	0.126
RD_T	0.808	0.807	0.245	0.005	1	-0.022	0.176	0.086
ZYC	0.185	-0.152	0.085	-0.104	-0.022	1	0.272	0.109
ZYI	0.129	0.176	0.138	-0.001	0.176	0.272	1	0.43
RA	0.113	0.116	0.167	0.126	0.086	0.109	0.43	1

Fig 6. The correlation of variables

TIO and RD_T exhibit a greater connection with the dependent variable EETIA. TIO should be the key independent variable, yet there could be a likelihood that TIO and RD_T exhibit collinearity. So, the VIF collinearity test is necessary.

The results of the variance inflation factors (VIF) are listed in Table 3. There is no multi-collinearity problem because the mean value of the VIF is 1.940 and the values of the VIF for all the variables are less than 10. Through the Hausman test, the results show that the fixed-effect model is more suitable for the research on the topic in this paper.

Table 3. VIF collinearity test

Variable	VIF	1/VIF
TIO	3.830	0.261
RD_T	3.500	0.286
ZYI	1.370	0.730
RD_EGR	1.310	0.765
RA	1.260	0.791
ZYC	1.170	0.855
RD_PGR	1.130	0.888
Mean	1.940	0.654

The time and individual fixed effect model show the least value of standard deviation when looking at robust standard deviation. Model 4 reveals that merely resource circulation is not relevant to EETIA in the complete process of dynamic resource change, showing that resource transfer is not largely conducted via conference exchanges. In contrast, the RA radiation impact is large, indicating that resource transfer may be a consequence of regional radiation. Furthermore, the specific conclusions regarding the assumption are as follows (**Table 4**):

H1 postulates that the TIO exerts pressure on the environmental carrying capacity and has a detrimental impact on EETIA in the near run. The regression coefficient k is -0.123 and $p < 5\%$, so the short period 2018 to 2019 is significant that relates a short term, which symbolizes TIO has is negative to EETIA in the short term and **H1** is supported.

H2a hypothesizes that the human resources accelerate the process of environmental resource consumption and have a negative effect on EETIA in the short term. The findings demonstrated that RD_PGR has significant effects on EETIA. The regression coefficient k is -0.148 and $p < 5\%$ in the short term, which represents human resources are detrimental to EETIA in the short term and **H2a** is supported.

H2b hypothesizes that the financial resources expand the development of environmentally friendly materials and have a positive effect on EETIA in the short term. The regression coefficient k is 0.094 and $p < 5\%$. Financial resources play a pivotal role in fostering innovation, providing the necessary capital for research, development, and implementation of sustainable practices so the financial resources are positive to EETIA and **H2b** is supported.

Table 4. The results comparsion of four models

	Model 1	Model 2	Model 3	**Model 4**
	Mixed OLS	Random Effects	Fixed Effects	**Time and Individual Fixed**
TIO	0.135***	-0.205***	-0.040	-0.123***
	(0.030)	(0.055)	(0.040)	(0.039)
RD_PGR	-0.112**	-0.181***	-0.187***	-0.148***
	(0.049)	(0.026)	(0.025)	(0.031)
RD_EGR	-0.058**	0.140***	0.046	0.094***
	(0.029)	(0.038)	(0.028)	(0.029)
RD_T	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
ZYC	0.002***	0.000	0.001***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
ZYI	-0.144**	0.264	0.012	0.441*
	(0.059)	(0.184)	(0.110)	(0.216)
RA	0.092	-0.106	0.011	-0.111*
	(0.061)	(0.065)	(0.071)	(0.057)
2016.year				0.000
				(.)
2017.year				-0.011
				(0.007)
2018.year				-0.033**
				(0.013)
2019.year				-0.045***
				(0.015)
_cons	0.010	0.283*	0.176*	0.001
	(0.054)	(0.150)	(0.093)	(0.195)
N	120.000	120.000	120.000	120.000
r2	0.759	0.388		0.473
r2_a	0.744	0.350		0.425

Robust standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

H2c hypothesizes that the project resources have a corresponding effect on EETIA according to the content of the project in the short term. The regression coefficient k is 0.0 nd the $p < 5\%$, which explains project resources may have no relationship with EETIA in the short term and **H2c** is not supported.

H3 hypothesizes that resource circulation has an effect on EETIA in the short term. The regression coefficient k is 0.0 and the $p > 10\%$. therefore resource circulation, individuals sharing about experience, has no impact on the EETIA in short time, which represents **H3** is not supported.

H4 hypothesizes that regional resource radiation accelerates technological innovation while putting strain on the environment by transporting resources across areas, which has a short-term negative impact on EETIA. The regression coefficient k is -0.111 and $p < 5\%$, so the regional radiation effect not only facilitates innovation but also places strain on the environment due to resource transportation. This implies that regional radiation effect has an adverse effect on EETIA within a limited timeframe and **H4** is supported.

H5 hypothesizes that the influence of technological innovation output will optimize energy structure and improve the ability to green environment, which has a positive impact on EETIA in the long term. Technological innovation output influence, a continuation of the first process, becomes the second process to improve the environment. The regression coefficient k is 0.441 and $p < 5\%$, the influence of technological innovation output has positive effect on EETIA in the long term and **H5** is supported.

In conclusion, TIO has a negative influence on EETIA in the short term, but having a positive effect on EETA in the long term. The first process shows that EETIA is the barrier to the environmental governance in the short term.

But in the long run, innovation-driven development is beneficial to construct the ecological, environmental, and technological innovation atmosphere by viewing the positive regression coefficient of ZYI, which demonstrates that resources have a favorable influence after a long time.

5.2. Robustness Test

To test the stability of results, the robustness test is needed. Inccreasing the sample size via bootstrap, decreasing the number of the control variables, and substituting the independent variable with synonymous ones (Giamattei, 2023)[43] are common mentods to do the stability test. The TOPSIS method is used to define EETIA in a similar sense. Defing three independent variables: y1 (EETIA itself is defined above), y2 and y3 and the specific indicators are shown in **Table 5**.

The add samples scheme was established by bootstrapping a bigger sample size, and the Reduce variables scheme was created by reducing the factors that affected transmission process, such as regional radiation, resource circulation, and innovation output impact. The dependent variable synonymous substitution is accomplished by modifying the meaning of the dependent variable. The outcomes of robustness test are as follows:

The primary findings of this study remain stable, as shown by Table 6 which demonstrates that the crucial independent variable TIO has a consistently negative impact on EETIA in the short term. The test of y2, lack of government engagement, clearly illustrates that government engagement is an essential prerequisite for the regional radiation effect.

Table 5. The results comparison of four models

EETIA	Index	Explaination
y1	Green environment	Greenness Index
	growth atmosphere of technological output	Growth rate of graduate student enrollment
		Growth rate of the number of published scientific papers
		Growth rate of the number of technological works published
		Growth rate of effective invention patents
y2	economic growth	green degree index of economic growth
	carrying potential of environment	carrying potential index of resources and environment
	growth atmosphere of scientific and technological output	Growth rate of graduate student enrollment
		Growth rate of the number of published scientific papers
		Growth rate of the number of technological works published
		Growth rate of effective invention patents
y3	economic growth	green degree index of economic growth
	carrying potential of environment	carrying potential index of resources and environment
	growth atmosphere of scientific and technological output	Proportion of doctoral students
		Technological papers published per capita
		Technological works published per 1,000 R&D personnel
		Effective invention patents per 100 R&D personnel

Table 6. The results comparison of four models

	Add samples	Reduce	Dependent variable synonymous substitution		
	EETIA	EETIA	Y1	Y2	Y3
TIO	-0.123**	-0.105**	-0.123***	-0.060*	-0.129***
	(0.059)	(0.041)	(0.039)	(0.033)	(0.044)
RD_PGR	-0.148***	-0.133***	-0.148***	-0.002	-0.140***
	(0.041)	(0.026)	(0.031)	(0.020)	(0.032)
RD_EGR	0.094**	0.080**	0.094***	0.040**	0.091***
	(0.038)	(0.033)	(0.029)	(0.018)	(0.032)
RD_T	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ZYC	0.000		0.000	-0.000	0.000
	(0.000)		(0.000)	(0.000)	(0.000)
ZYI	0.441*		0.441*	-0.034	0.454**
	(0.262)		(0.216)	(0.094)	(0.213)
RA	-0.111*		-0.111*	-0.029	-0.109*
	(0.090)		(0.057)	(0.035)	(0.062)
2016.year	0.000	0.000	0.000	0.000	0.000
	(0.000)	(.)	(.)	(.)	(.)
2017.year	-0.011	-0.021**	-0.011	-0.002	0.009
	(0.010)	(0.008)	(0.007)	(0.005)	(0.007)
2018.year	-0.033**	-0.034**	-0.033**	-0.003	-0.012
	(0.014)	(0.013)	(0.013)	(0.006)	(0.014)
2019.year	-0.045**	-0.046***	-0.045***	-0.013*	-0.025
	(0.018)	(0.016)	(0.015)	(0.007)	(0.015)
_cons	0.001	0.326***	0.001	0.246***	-0.003
	(0.234)	(0.050)	(0.195)	(0.084)	(0.196)
N	120.000	120.000	120.000	120.000	120.000
r2	0.473	0.409	0.473	0.699	0.367
r2_a	0.425	0.372	0.425	0.671	0.309

Robust standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.3. Futher Study on the Relationship of EETIA and TIO

5.3.1. Grouping Regions

Further study is divided into two parts: grouping regions and policy stimulation. Grouping regions follows the categorization rules of the “Statistical Yearbook” to classify provinces into three parts: eastern, central, and western (Jin, 2019)[29]. This enables us to better analyze the effect of TIO on EETIA in each location.

Table 7. The results comparsion of four models

	Eastern	Western	Central
	EETIA	EETIA	EETIA
TIO	-0.216***	-0.034	0.135
	(0.067)	(0.145)	(0.102)
RD_PGR	-0.222***	-0.122**	-0.012
	(0.035)	(0.048)	(0.091)
RD_EGR	0.106***	0.066	-0.163*
	(0.029)	(0.085)	(0.067)
RD_T	0.000***	0.000	-0.000
	(0.000)	(0.000)	(0.000)
ZYC	0.000	0.000	-0.001*
	(0.000)	(0.000)	(0.000)
ZYI	0.223	0.576	1.017
	(0.480)	(0.331)	(0.632)
RA	-0.025	-0.159	-0.310
	(0.088)	(0.108)	(0.228)
2016.year	0.000	0.000	0.000
	(.)	(.)	(.)
2017.year	-0.021	-0.018	0.030
	(0.012)	(0.015)	(0.029)
2018.year	-0.045*	-0.047	-0.003
	(0.021)	(0.031)	(0.023)
2019.year	-0.063**	-0.057	-0.017
	(0.021)	(0.034)	(0.040)
_cons	0.191	-0.203	-0.549
	(0.386)	(0.341)	(0.580)
N	44.000	52.000	24.000
r2	0.554	0.560	0.806
r2_a	0.419	0.453	0.657

Robust standard errors in parentheses
$^{*}\ p < 0.1$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$

As demonstrated in **table 7**, the effects of resources and regional radiation may be minimized or abolished as a consequence of the split of regional samples. Thus, we mainly analyze the two-point states of resource intake and resource output in this section. The imbalance regional data and regional itself may cause only the results of eastern area are corresponding to the main results. But the regression coefficient of eastern area changes from -0.123 to -0.216 owing to the lack of a transmission effect. RD_PGR is significant in western area, which shows Chinese present strategy, bringing in talented personnel, takes effect for the large-scale development of the western area. RD_EGR is significant in central area, which shows the central region has an excellent geographical location and is rich in resources.

5.3.2. Policy Simulation

Government intervation is crucial in the dual dynamic processes. To further investigate whether the government's environmental policies are effective for environmental governance. This paper establishs the policy variable using the 0-1 planning function. When the area implements this policy, the value of the policy variable will be assigned as 1; otherwise, it will be assigned as 0 in accordance with the 2016 and 2017 policies: "The Basic Ideas of the 13th Five-Year Plan for Environmental Protection" and "Winning the Blue-Sky Defense War". The did model is established as follows:

$$EETIA_{it} = \beta_0 + \beta_1 TIO_{it} + \beta_2 RD_{PGR_{it}} + \beta_3 RD_{EGR_{it}} + \beta_4 RD_{T_{it}} + \beta_5 ZYC_{it} + \beta_6 ZYI_{it} + \beta_7 RA_{it} + \beta_8 policy_i + \beta_9 time_i + \beta_{10}(policy_i \times time_i) + u_i + e_{it} \quad (15)$$

Assuming that post is $policy_i \times time_i$,and treated is $policy_i$, the DID model is calculated, and the result is as follows:

Table 8 shows the regression coefficient of TIO to EETIA changes from -0.123 to -0.165, and the RA changes from -0.111 to -0.114, which demonstrates that government intervention increases the radiation effect and speeds up the first process of resource change. By controlling the first process, the realization of environment governance will be accelerated.

Table 8. The results of policy intervene

Did Model	(1)
	EETIA
TIO	-0.165***
	(0.041)
RD_PGR	-0.173***
	(0.027)
RD_EGR	0.114***
	(0.030)
RD_T	0.000***
	(0.000)
ZYC	0.000
	(0.000)
ZYI	0.413*
	(0.204)
RA	-0.114**
	(0.054)
treated	0.021*
	(0.011)
post	0.022**
	(0.010)
_cons	0.034
	(0.188)
N	120.000
r2	0.482
r2_a	0.440

Robust standard errors in parentheses
$^{*} p < 0.1$, $^{**} p < 0.05$, $^{***} p < 0.01$

5.4. Summary

According to the analysis above, Two dynamic and continuous processes construct a system that affects environmental governance. The first process, including resource changes and TIO, has the short-term negative impact on environmental governance and the second process, including the influence of TIO, has the long-term positive impact on environmental governance. Furthermore, the second process's growth benefits exceed the first process's downsides. Building on the findings, this article raises that: accelerating the first process will facilitate a quicker realization of the second process, and ultimately enhance the environmental governance. Based on the above results, two suggestions are introduced: Based on the aforementioned findings, two recommendations are proposed: expedite the transfer of resources by government involvement in the environment and implement extensive development in the western area to ensure equitable regional progress.

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Appendix

Table 9. The mean radiation scores of all province

Year	Region	RA	Region	RA
2016	Beijing	0.3337	Henan	0.5040
2017	Beijing	0.3343	Henan	0.5285
2018	Beijing	0.2828	Henan	0.5379
2019	Beijing	0.3316	Henan	0.5263
2016	Tianjin	0.4629	Hubei	0.5121
2017	Tianjin	0.4834	Hubei	0.5209
2018	Tianjin	0.4845	Hubei	0.5120
2019	Tianjin	0.4680	Hubei	0.4435
2016	Hebei	0.5232	Hunan	0.4905
2017	Hebei	0.4331	Hunan	0.4903
2018	Hebei	0.4751	Hunan	0.4830
2019	Hebei	0.3543	Hunan	0.4042
2016	Shanxi	0.5194	Guangdong	0.2838

2017	Shanxi	0.5113	Guangdong	0.3444
2018	Shanxi	0.4758	Guangdong	0.3221
2019	Shanxi	0.5258	Guangdong	0.3015
2016	Neimenggu	0.4748	Guangxi	0.3569
2017	Neimenggu	0.3712	Guangxi	0.3422
2018	Neimenggu	0.4618	Guangxi	0.3575
2019	Neimenggu	0.3627	Guangxi	0.3350
2016	Liaoning	0.3343	Hainan	0.1686
2017	Liaoning	0.3315	Hainan	0.3733
2018	Liaoning	0.3444	Hainan	0.3220
2019	Liaoning	0.3651	Hainan	0.4883
2016	Jilin	0.2922	Chongqing	0.4430
2017	Jilin	0.3126	Chongqing	0.4640
2018	Jilin	0.3124	Chongqing	0.4287
2019	Jilin	0.3102	Chongqing	0.4426
2016	Heilongjiang	0.2544	Sichuan	0.3787
2017	Heilongjiang	0.2279	Sichuan	0.4005
2018	Heilongjiang	0.2330	Sichuan	0.3996
2019	Heilongjiang	0.2509	Sichuan	0.3736
2016	Shanghai	0.3586	Guizhou	0.4269
2017	Shanghai	0.4113	Guizhou	0.4267
2018	Shanghai	0.3615	Guizhou	0.4135
2019	Shanghai	0.3534	Guizhou	0.3919
2016	Jiangsu	0.4818	Yunnan	0.3381
2017	Jiangsu	0.4375	Yunnan	0.2912
2018	Jiangsu	0.3676	Yunnan	0.3384
2019	Jiangsu	0.3462	Yunnan	0.3085
2016	Zhejiang	0.4614	Shanxi	0.3498
2017	Zhejiang	0.4536	Shanxi	0.4876
2018	Zhejiang	0.4226	Shanxi	0.5172
2019	Zhejiang	0.3907	Shanxi	0.4941
2016	Anhui	0.5081	Gansu	0.2897
2017	Anhui	0.5150	Gansu	0.4122
2018	Anhui	0.5128	Gansu	0.4555
2019	Anhui	0.4841	Gansu	0.4484
2016	Fujian	0.3905	Qinghai	0.4153
2017	Fujian	0.4012	Qinghai	0.2681
2018	Fujian	0.3890	Qinghai	0.4080
2019	Fujian	0.4010	Qinghai	0.1614
2016	Jiangxi	0.4067	Ningxia	0.4366
2017	Jiangxi	0.4733	Ningxia	0.3926
2018	Jiangxi	0.4878	Ningxia	0.4698
2019	Jiangxi	0.4286	Ningxia	0.4391
2016	Shandong	0.4923	Xinjiang	0.0669
2017	Shandong	0.5107	Xinjiang	0.0669
2018	Shandong	0.5189	Xinjiang	0.0619
2019	Shandong	0.5122	Xinjiang	0.0584