

Article

Do Economic Growth Targets Aggravate Environmental Pollution? Evidence from China

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Abstract

How to balance the relationship between economic development and environmental protection is a common challenge faced by developing countries. Based on panel data from 30 Chinese provinces between 2008 to 2021, we analyze the impact of economic growth targets (EGTs) on environmental pollution (EP) using a spatial autoregressive threshold panel (SARTP) model. The empirical findings are as follows. (1) A 1% increase in the EP index in adjacent provinces leads to a 0.5870% increase in the observing province. (2) For provinces with EGTs above 7.5%, a 1% increase in the EGT results in a 0.3799% increase in the EP index. Conversely, its impact on EP is not significant. (3) As EGTs increase, the EP effect intensifies in central provinces, weakens in western provinces, and remains insignificant in eastern provinces; the EP effect of EGTs is significantly greater in provinces with a large population size and a low proportion of tertiary industry. (4) When the provincial EGT exceeds the central target by 0.5%, a 1% increase in the EGT results in a 0.4469% increase in the EP index. Our paper offers theoretical and empirical insights for alleviating EP and promoting sustainable economic development.

Keywords: economic growth target; environmental pollution; threshold effect; SARTP model; top–down amplification of economic growth targets



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1. Introduction

Since the reform and opening up, China's economy has maintained a high growth rate and achieved remarkable accomplishments. These achievements have been accompanied by significant adjustments in economic structure and the gradual improvement of the industrial system. However, rapid industrialization, urbanization, and continuous population growth have significantly exacerbated environmental pollution (EP). Severe environmental pollution has become a major obstacle to sustainable economic development and social well-being [1]. In response to increasingly severe EP, the Chinese government has implemented a series of proactive reforms in pollution control. In 1998, the government established sulfur dioxide pollution control zones. In 2006, it incorporated environmental protection into the performance evaluation system for government officials. In 2013, the government launched the air pollution prevention and control action plan. This series of measures marks a gradual shift in China's environmental regulations from lenient to strict, achieving significant pollution control results while maintaining rapid economic growth. However, China ranked 118th out of 178 countries and regions in the 2014 Global Environmental Performance Index, indicating the severity of its environmental pollution.

Balancing economic development with environmental protection remains a major challenge for the Chinese government.

In regional economic development, local governments play a crucial role as key policymakers and executors in promoting economic growth [2]. Local governments accelerate local economic growth by implementing economic policies and investment strategies and promoting infrastructure development. However, while dedicated to economic development, local governments must navigate the complex challenges of balancing economic growth with environmental protection [3]. In response to the urgent need for rapid economic growth, local governments often prioritize resource allocation to sectors that promise quick returns, such as heavy industry and real estate. Certainly, these sectors contribute to GDP growth and fiscal revenues, but they also pose serious environmental challenges. For example, air and water pollution from industrial emissions, along with ecological degradation due to land over-exploitation, pose serious threats to the natural environment.

In China, the central government influences local government decisions by formulating regional development targets [4,5]. Economic growth targets (EGTs) and environmental policies set by the central government provide a decision-making framework for local governments, requiring them to balance economic growth and environmental protection within this framework [6]. The central government's regulatory mechanism requires local governments to adhere to national strategic objectives; otherwise, they risk reduced resources or failing assessment standards [7]. To mitigate these risks, local governments often prioritize economic growth over environmental protection due to various factors [8]. On one hand, the traditional performance evaluation system centered on the GDP leads local government officials to prioritize short-term economic growth over long-term environmental protection benefits [9]. On the other hand, environmental protection often demands significant capital investment and technical support. Local governments with limited financial resources may struggle to balance economic growth with environmental protection. Thus, protecting the environment while sustaining economic growth is a difficult challenge for local governments. When setting EGTs, local governments are often given clear phased targets. These targets are carefully planned and decomposed into a series of concrete, feasible, and hard-bound quantitative indicators. To achieve EGTs, the central government has motivated local governments through incentives and assessment systems. It is noteworthy that the official selection mechanism based on rankings of economic development performance serves as the intrinsic motivation driving local officials to pursue economic growth. While this mechanism encourages local governments to boost the economy, it may also cause them to overlook environmental protection. Therefore, when discussing economic growth, it is essential to fully consider the EGTs, particularly their potential impact on EP, and implement effective mitigation measures to reduce the negative effects.

Existing research on EGTs primarily focuses on the motivations for target setting, governmental behavioral responses, and macroeconomic performance [10–12] while largely neglecting their specific impact on EP. Although the literature has examined the influencing factors, regional heterogeneity, and dynamic characteristics of EP [13–15], the direct linkage between EGTs set by local governments and EP has not yet been systematically explored. In addition, traditional linear regression methods fall short in simultaneously capturing the spatial spillover effects of EP and the potential nonlinear threshold effects under the influence of EGTs [16,17], which may result in biased estimates and conflicting conclusions. Meanwhile, some scholars have noted the incentive effect of local governments setting EGTs higher than those set by the central government [18,19], but they have not yet precisely quantified the relationship between the extent to which local governments set EGTs above those set by the central government and EP. This study addresses these gaps by employing

a spatial autoregressive threshold panel (SARTP) model to quantify the impact of EGTs on EP.

This study aims to address following questions. (1) Is there a significant spillover effect of EP? (2) Is there a significant threshold effect of EGTs on EP under varying EGT settings? (3) Does the top–down amplification of EGTs exacerbate the EP effects of these targets? To investigate these questions, we employ a SARTP model to explore the nonlinear impact of EGTs on EP and the spatial spillover effect of EP. Meanwhile, we use this model to identify the relationship between top–down amplification of EGTs and the EP effects of these targets. Furthermore, we assess the nonlinear impacts of EGTs on EP in provinces with varying geographies, population sizes, and industrial structures.

This study makes following contributions. (1) Enrichment of research on the socio-economic causes of EP. Existing research on EP primarily examines its influencing factors, regional differences, and dynamic characteristics. Unlike previous studies, we adopt a unique perspective of EGTs, focusing on the nonlinear impact of EGTs set by local governments on EP. (2) Methodological advancement. Traditional linear regression methods are inadequate for effectively addressing spatial effects and nonlinear relationships. Unlike previous methods, we are the first to employ the SARTP model to capture both the spatial spillover effects of EP and the nonlinear threshold effects of EGTs on EP, significantly enhancing estimation accuracy and explanatory power. (3) Heterogeneous analysis. We explore the heterogeneous effects of EGTs on EP from three perspectives, geographical location, population size, and industrial structure, providing references for designing targeted environmental protection policies and economic growth strategies. (4) Quantitative analysis. Most existing research emphasizes qualitative analysis, examining the relationship between local and central government EGTs. For the first time, we quantify the specific relationship between the magnitude by which provincial EGTs exceed central government targets and the EP index, providing a quantitative basis for setting reasonable EGTs to protect the environment.

The paper is structured as follows. Section 2 covers the literature review. Section 3 delves into theoretical mechanisms and research hypotheses. Section 4 introduces the theoretical model. Section 5 focuses on variable selection and empirical model construction. Section 6 presents the empirical analysis. Conclusions, policy implications, and limitations are given in Section 7.

2. Literature Review

2.1. Related Research on EGTs

An EGT typically influences the allocation and utilization of resources, thereby impacting economic growth [20]. While an EGT can drive resource investment and economic expansion in the short term, it may not effectively enhance the quality and sustainability of long-term economic development [21]. On the one hand, EGTs set by local governments are often shaped by both horizontal and vertical competition. Horizontal competition occurs among governments at the same level. For instance, local governments set competitive EGTs to attract production factors and enhance their advantages. While this competition can improve governance efficiency and optimize resource allocation, it may also result in excessive rivalry and resource waste [22]. Vertical competition exists between local and central governments, with local governments actively seeking preferential policies and resource support from the central government to meet their economic growth targets. On the other hand, a performance-based promotion system aims to motivate local officials by linking rewards and punishments to their fiscal revenue growth and target achievements [23]. However, this mechanism poses a risk, as it may lead local officials to set excessive or unrealistic EGTs for short-term personal gain [24,25]. Faced with unrealistic

targets, local governments often prioritize short-term economic growth over environmental protection and long-term sustainability [26].

The setting of EGTs is influenced by two main constraints: external and internal. External constraints primarily arise from the central government, which uses the GDP's growth rate as a key indicator to assess local development effectiveness and officials' promotion prospects. Consequently, motivated by career advancement, local officials often set ambitious EGTs to demonstrate their governance capabilities to higher-level governments, resulting in the top-down amplification of EGTs [27]. Meanwhile, local governments adopt stricter, rigid measures in terms of internal constraints. Specifically, local governments impose significant pressure on themselves by setting hard EGTs. This rigid constraint mechanism forces local governments to go all out, even striving to exceed EGTs. However, this high-intensity pressure to meet targets leads to distortions in resource allocation by local governments, thereby triggering negative consequences, such as environmental degradation and excessive resource exploitation [28].

2.2. Related Research on EP

In recent years, research on EP has focused on how factors like economic and population agglomeration impact the environment [29,30]. Based on panel data from 74 cities within China's Yellow River Basin between 2005 and 2016, Wang et al. (2022) [31] identified the relationship between economic agglomeration and haze pollution using a spatial Durbin model. Their findings indicated that haze pollution rises during the early stage of economic agglomeration and declines as it matures. As economic agglomeration deepens, its demand for and attraction to the population will increase [32]. Excessive population concentration can lead to heightened pollution emissions, significantly worsening environmental issues. However, some scholars have argued that population agglomeration can lower resource consumption and reduce EP [33].

In addition to economic and demographic factors influencing EP, the role of the government is crucial. An inefficient government can exacerbate EP issues due to its limited capacity for effective environmental protection [34]. Conversely, a stable and knowledgeable government is essential for mitigating environmental degradation, as it can better plan and implement environmental policies while effectively addressing environmental challenges [35]. It is important to note that some scholars highlight the government's crucial role in regulation and policymaking for EP control [36]. Zheng (2023) [37] found that multi-party cooperation, interactive monitoring, and benefit compensation can enhance local government collaboration in haze control. When environmental preferences are high, government regulation effectively reduces pollution emissions [38]. Additionally, based on panel data from 223 Chinese cities between 2005 and 2014, Shen et al. (2024) [28] explored the impact of EGTs on haze pollution using spatial autoregressions and other models. Their findings suggested that EGTs can significantly increase haze pollution.

2.3. Related Research on the EGT–EP Relationship

An EGT is related to EP in complex ways. Existing studies found that local governments often prioritize high-energy-consuming and high-emission industries to achieve economic growth, which worsens EP [16,39]. Moreover, the official promotion mechanism linked to GDP strengthens the short-term economic growth orientation, neglecting the environmental costs [2,40]. However, some studies have pointed out that including environmental protection in performance evaluations can shift EGTs towards a green orientation [41]. Currently, there are still few studies on the impact of EGTs on EP. Chai et al. (2021) [42] noted that the constraint of EGTs on air pollution has a significant threshold effect, with the inhibitory effect strengthened by industrial structure adjustments. Ren et al.

(2023) [43] suggested that environmental decentralization can mitigate the adverse effects of EGT constraints on pollution. While these studies have shown results, systematic research on the impact of provincial EGTs on EP remains limited and needs further investigation.

In summary, existing research has mainly focused on the impact of factors like economic agglomeration, population agglomeration, and government regulation on EP and pollution control. However, few scholars have examined how EGTs affect EP. Additionally, existing methods have failed to effectively capture the spatial characteristics of EP and the potential nonlinear effects of related factors simultaneously, leading to biased estimates and contradictory conclusions. This paper aims to explore whether EGTs influence EP using a SARTP model. Moreover, the study identifies heterogeneous characteristics of the impact of EGTs on EP.

3. Theoretical Mechanisms and Research Hypotheses

3.1. EGTs and EP

Recently, the link between economic growth and environmental protection has gained renewed attention. Nations increasingly recognize that pursuing economic progress at the expense of environmental conservation is unsustainable. On one hand, economic growth is a vital goal for governments worldwide, closely tied to national development, social progress, and people's well-being. On the other hand, EP, as a byproduct of economic growth, has significant and irreversible effects. If not effectively managed, EP will severely hinder sustainable economic development [44,45]. Due to relaxed environmental regulations and hindered industrial upgrades, along with suppressed technological innovation, EGTs have risen across all levels of organizations [16]. However, this persistent growth worsens regional EP and poses serious challenges for environmental protection [46]. While government-set EGTs promote economic expansion, they can also lead to the diversion of funds away from environmental protection and green technology investment, exacerbating EP [47]. Absolute EGTs significantly raise carbon emissions in horizontal competition, whereas relative targets do so in vertical competition [48].

It is important to note that local governments often prioritize high economic growth for political gains at the expense of environmental protection and balanced regional development. Specifically, government-set EGTs frequently exceed the local economy's actual capacity. These ambitious goals are typically influenced by political pressure, performance evaluations, or rivalry with other regions [49,50]. When under high growth pressures, local governments may favor economic measures that yield short-term results. These short-term measures often neglect their long-term effects on the environment, resources, and social well-being [51]. For instance, to achieve high EGTs, local governments prioritize land quotas for traditional industrial sectors. This resource tilt exacerbates EP [28]. Meanwhile, the upgrading and substitution process of traditional polluting industries may be delayed, resulting in the continued existence of EP. Additionally, local governments compete to lower environmental standards and relax regulations to attract investment and boost economic growth. This behavior not only degrades environmental quality but also heightens unfair regional competition [52]. Regions with strict environmental standards may face higher costs and lose competitive advantages, while those that relax such standards might achieve short-term economic growth. Guo et al. (2024) [17] found that higher EGTs primarily lead to increased pollution emissions by reducing investments in pollution control. Therefore, we put forth the following hypothesis:

Hypothesis 1. *EGTs have a nonlinear impact on EP. Specifically, setting high EGTs significantly increases EP.*

3.2. EGT Constraint and EP

The constraint strength of EGTs indicates the reasonableness of their setting. The internal constraints of EGTs emphasize the limitations that local governments themselves face in terms of resources and capabilities [53], which restrict the ways local governments act to achieve EGTs. If an EGT is set too high, exceeding the existing resources and capabilities of local governments, it may lead to difficulties in policy implementation, an increase in short-term behavior, and, ultimately, environmental problems.

External constraints emphasize the influence and pressure exerted by the central government on EGTs set by local governments. These targets are usually directly linked to the performance evaluations of local officials. Local governments need to achieve these targets to gain political recognition and ensure that their leadership positions are not affected [54]. To demonstrate their capability and determination to the central government, local governments tend to establish elevated EGTs. Consequently, EGTs from the central government down to local governments exhibit a trend of gradual expansion [55]. Additionally, local governments set EGTs higher than those of their peers primarily to stand out in the competition among local governments [56]. This tendency to establish excessively high EGTs reflects not only fierce competition among local governments but also a strong drive for performance and promotion. Under pressure to achieve EGTs, local governments may adopt measures that are detrimental to long-term sustainable development [16]. A common practice is to distort resource allocation by directing more resources towards sectors that can rapidly stimulate economic growth, prioritizing EGTs over environmental costs [18]. For instance, local governments may prioritize land needs for high-profit, quick-return projects, such as industrial production, while neglecting the land needs of environmental protection industries or green technologies, thereby exacerbating EP. Additionally, to focus funds on achieving EGTs, local governments often invest in areas that yield immediate benefits but conflict with green development principles. Meanwhile, local governments may cut budgets for environmental protection infrastructure. This approach results in ineffective pollution control measures and exacerbates EP [43]. Therefore, we put forth the following hypothesis:

Hypothesis 2. *Top-down amplification of EGTs aggravates their EP effect.*

4. Theoretical Methodology

4.1. SARTP Model

When analyzing the relationship between EGTs and EP, traditional spatial regression models and panel data methods struggle to handle both spatial autocorrelation and potential nonlinear effects simultaneously. For example, Chai et al. (2021) [42] used a spatial Durbin model to analyze the spillover effects of air pollution and a threshold panel model to assess the nonlinear impact of EGTs on air pollution. Shen et al. (2024) [28] constructed a fixed effects model to assess the average impact of EGTs on haze pollution and then applied a spatial econometric framework to examine the spatial spillover characteristics of haze pollution. In contrast, the SARTP model simultaneously captures both the spatial spillover effect of EP and the nonlinear influence of EGTs on EP by incorporating a spatial lag term and a threshold effect. Thus, it offers a more accurate and comprehensive analytical framework for this study, addressing the shortcomings of existing methods.

The threshold panel model divides data into different intervals by setting thresholds, with each interval having distinct regression coefficients. This model reveals the nonlinear

relationships between variables. Hansen (1999) [57] first introduced the single-threshold panel model as follows:

$$y_{it} = \beta_1' x_{it} I(q_{it} \leq \gamma) + \beta_2' x_{it} I(q_{it} > \gamma) + \mu_i + \varepsilon_{it}, \quad i = 1, \dots, N, \quad t = 1, \dots, T \quad (1)$$

where the subscript i represents the i -th individual, t denotes the t -th year, y_{it} is the observations of the dependent variable, x_{it} is the observations of the explanatory variable, q_{it} signifies a threshold variable, β_1 and β_2 denote the regression coefficients of the different regimes, $I(\bullet)$ is an indicator function, u_i stands for individual fixed effects, and $\varepsilon_{it} \sim iid(0, \sigma^2)$ is the random error term. Equation (1) considers the single-threshold case, which can be extended to the multi-threshold case according to the steps of the measurement test of sample data.

Adding a spatial autoregressive term to the single-threshold panel model results in the single-threshold SARTP model [58]:

$$y_{it} = \rho \sum_{j=1}^N W_{ij} y_{jt} + \beta_1' x_{it} I(q_{it} \leq \gamma) + \beta_2' x_{it} I(q_{it} > \gamma) + \mu_i + \varepsilon_{it} \quad (2)$$

where ρ stands for the spatial correlation coefficient, W_{ij} is the spatial weight, and other variables are the same as Equation (1).

4.2. Test of Threshold Effect and Threshold Number

It is essential to verify the threshold effect and determine the number of regimes before conducting empirical analysis with the SARTP model. The hypothesis of no threshold effect is $H_{10} : \beta_1 = \beta_2$, and the alternative hypothesis is $H_{11} : \beta_1 \neq \beta_2$. We construct the F statistic defined as $F_1 = \frac{S_0 - S_1(\hat{\gamma})}{\hat{\sigma}^2}$ to test whether the SARTP model has a threshold. S_0 and $S_1(\hat{\gamma})$ represent the residual sum of squares (RSS) under H_{10} and H_{11} , respectively. $\hat{\sigma}^2 = \frac{1}{N(T-1)} S_1(\hat{\gamma})$ serves as the consistent estimator of σ^2 . We obtain the asymptotic distribution and P value of F_1 using the bootstrap method.

When a threshold effect exists, the number of thresholds must be determined. The null hypothesis is H_{20} : Only one threshold exists, and the alternative hypothesis is H_{21} : Two thresholds exist. We construct the LR statistic defined as $LR_1 = \frac{S_1(\hat{\gamma}_1) - S_1(\hat{\gamma}_2)}{\hat{\sigma}_*^2}$ to verify whether H_{20} holds. $S_1(\hat{\gamma}_1)$ and $S_1(\hat{\gamma}_2)$ signify the RSS under H_{20} and H_{21} , respectively. $\hat{\sigma}_*^2 = \frac{1}{N(T-1)} S_1(\hat{\gamma}_2)$ is the consistent estimator of σ_*^2 . When there are more than two regimes, the corresponding test method can be performed similarly.

5. Variable Selection, Empirical Model Construction, and Data Description

5.1. Variable Selection

Environmental pollution (EP) is the dependent variable. We create an EP index system composed of wastewater discharge, SO₂ discharge, and general industrial solid waste production [59,60]. In this paper, the entropy method calculates the EP index for 30 Chinese provinces from 2008 to 2021. The detailed description of the EP index's construction can be found in Appendix A.

An economic growth target (EGT) serves as the core explanatory variable. An EGT refers to the GDP growth rate a country or region aims to achieve over time [61]. An EGT includes not just the concept of speed but the unity of quantity and quality. It emphasizes the coordination of economic proportions, structural optimization, and sustainable development while maintaining a moderate economic growth rate. We collected data on EGTs from Chinese provincial government reports.

Top-down amplification of economic growth targets (*PNGAP*) is the threshold variable. We measure this variable according to the difference between provincial and central EGTs [27].

EP is influenced not only by EGTs but also by various internal and external factors. To accurately assess the impact of these factors on EP, we select the following control variables based on the existing literature.

Openness (*OPEN*). While opening up can drive rapid economic growth, it also leads to increased resource consumption. This excessive consumption not only worsens resource scarcity but may also cause environmental damage [62]. Openness is measured by the ratio of total import and export trade to regional GDP.

Environmental regulation (*ER*). Environmental regulation encompasses laws, regulations, policies, and technical standards established by the government or relevant agencies to protect the environment and mitigate pollution. These measures aim to reduce EP by limiting industrial activities, raising emission standards, and promoting cleaner production and technological innovation [63]. The investment ratio in pollution control to industrial added value reflects environmental regulation.

Foreign direct investment (*FDI*). FDI can enhance economic scale but may also lead to increased resource consumption and pollution. Neglecting environmental protection while attracting foreign investment could exacerbate pollution issues [64]. Foreign direct investment is indicated by its proportion in regional GDP.

Technological investment (*TECH*). Technological investment drives innovation, leading to greener production technologies. Advanced environmental protection technologies can effectively treat and restore polluted environments [65]. Technological investment is defined as the ratio of fiscal expenditure on science and technology to general budget expenditure in each region.

Industrial agglomeration (*IA*). During the early stages of industrial agglomeration, underdeveloped infrastructure leads to enterprise competitiveness relying heavily on production factor inputs. This may prompt governments to relax environmental regulations to boost economic growth, worsening pollution [66]. To measure industrial agglomeration, we use the proportion of employed individuals to the area of the regional administrative division.

R&D intensity (*RD*). With increased R&D intensity, enterprises can create more environmentally friendly and energy-efficient production technologies and products. The use of these technologies significantly reduces pollutant emissions during production, thereby lessening EP [67]. R&D intensity is expressed as the ratio of internal R&D expenditure to gross regional product.

Informationization level (*IL*). The enhancement of informationization promotes rapid technological advancements in clean energy and pollution control technologies. These technologies help reduce pollutant emissions during production, improve resource utilization efficiency, and lower EP [68]. We chose the proportion of total postal and telecommunications businesses within the regional GDP to represent IL.

Energy consumption (*EC*). The widespread use of fossil fuels results in significant emissions of harmful gases, worsening the greenhouse effect and air pollution and contributing to environmental issues like acid rain [69]. Energy consumption is assessed by per capita energy consumption.

In conclusion, while EGTs can drive local governments to promote economic growth, they may also exacerbate EP. Meanwhile, factors like *OPEN*, *ER*, *FDI*, *TECH*, *IA*, *RD*, *IL*, and *EC* can influence EP in the process through which EGTs affect EP. For instance, overly high EGTs and *EC* may exacerbate EP. In this process, factors like *TECH* and *RD* can help mitigate EP by fostering technological advancements.

5.2. Empirical Model Construction

EP can spread pollutants to nearby areas via air, water, or soil. Thus, we explore the spatial spillover effect of EP using an SAR model. The model is as follows:

$$EP_{it} = \rho \sum_{j=1}^N W_{ij} EP_{jt} + \beta_1 EGT_{it} + \beta_2 Control_{it} + \mu_i + \varepsilon_{it} \quad (3)$$

where $i = 1, \dots, 30$, $t = 1, \dots, 14$, EP_{it} and EGT_{it} are, respectively, the environmental pollution index and economic growth targets for the i -th province in the t -th year, $Control_{it} = (OPEN_{it}, ER_{it}, FDI_{it}, TECH_{it}, IA_{it}, RD_{it}, IL_{it}, EC_{it})'$ comprises a vector of control factors, β_1 and β_2 stand for parameters to be estimated, ρ is the spatial correlation coefficient, $\sum_{j=1}^N W_{ij} EP_{jt}$ signifies the spatial lag term of the EP index, W_{ij} stands for the spatial weight of the geographical distance at the i -th and j -th provinces, μ_i denotes the individual fixed effect, and $\varepsilon_{it} \sim iid(0, \sigma^2)$ represents the random error term.

Based on Equation (3), we introduce a threshold effect to examine the nonlinear impact of EGTs on EP. Among them, EGT is included in the SARTP model as a threshold variable. The details are as follows:

$$EP_{it} = \rho \sum_{j=1}^N W_{ij} EP_{jt} + \beta_1' X_{it} I(EGT_{it} \leq \gamma_1) + \sum_{k=2}^{K-1} \beta_k' X_{it} I(\gamma_{k-1} < EGT_{it} \leq \gamma_k) + \beta_K' X_{it} I(EGT_{it} > \gamma_{K-1}) + \mu_i + \varepsilon_{it} \quad (4)$$

where $X_{it} = (EGT_{it}, OPEN_{it}, ER_{it}, FDI_{it}, TECH_{it}, IA_{it}, RD_{it}, IL_{it}, EC_{it})'$ serves as the core explanatory variable and all control variables; $\beta_k = (\beta_{k1}, \beta_{k2}, \dots, \beta_{k9})'$ denotes the regression coefficient vector for the core explanatory variable and control variables within the k -th regime; and γ_k signifies the threshold value. In discussing research hypothesis H2, simply replace the threshold variable in Equation (4) with $PNGAP$.

5.3. Data Source and Description

Excluded due to incomplete data in Tibet. Thus, we will analyze a panel dataset of 30 Chinese provinces between 2008 and 2021. The original data are sourced from the *China Statistical Yearbook*, the *China Labor Statistics Yearbook*, and the National Bureau of Statistics. The related variables and their descriptive statistical results are shown in Table 1, where missing values are filled using linear interpolation and logarithmic transformation is applied to certain variables with excessively large values.

Table 1. Descriptive statistical results for each variable.

Variable	Definition	Obs.	Mean	SD	Min	Max
<i>EP</i>	Environmental pollution	420	0.2373	0.1432	0.0155	0.6722
<i>EGT</i>	Economic growth target	420	0.0884	0.0212	0.0450	0.1500
<i>PNGAP</i>	Top-down amplification of EGTs	420	0.0162	0.0171	−0.0200	0.0700
<i>OPEN</i>	Openness	420	0.2775	0.3176	0.0076	1.6977
<i>ER</i>	Environmental regulation	420	0.0036	0.0034	0.0001	0.0310
<i>FDI</i>	Foreign direct investment	420	0.0214	0.0195	0.0001	0.1210
<i>TECH</i>	Technological investment	420	0.0208	0.0147	0.0039	0.0720
<i>IA</i>	Industrial agglomeration	420	0.0256	0.0371	0.0003	0.2171
<i>RD</i>	R&D intensity	420	0.0200	0.0148	0.0018	0.0704
<i>IL</i>	Informationization level	420	0.0670	0.0500	0.0170	0.2900
<i>EC</i>	Energy consumption	420	3.6638	1.8594	1.2234	11.9128

To describe the spatial distribution of EP in China, we analyze sample data from each province for 2008 and 2021. Figure 1 illustrates this distribution for both years. Overall, the EP index decreased in 2021 compared to 2006. Notably, the eastern and central regions exhibit higher pollution indices than the western regions, indicating more severe environmental issues in the former during the sample period, while western areas experience relatively minor pollution.

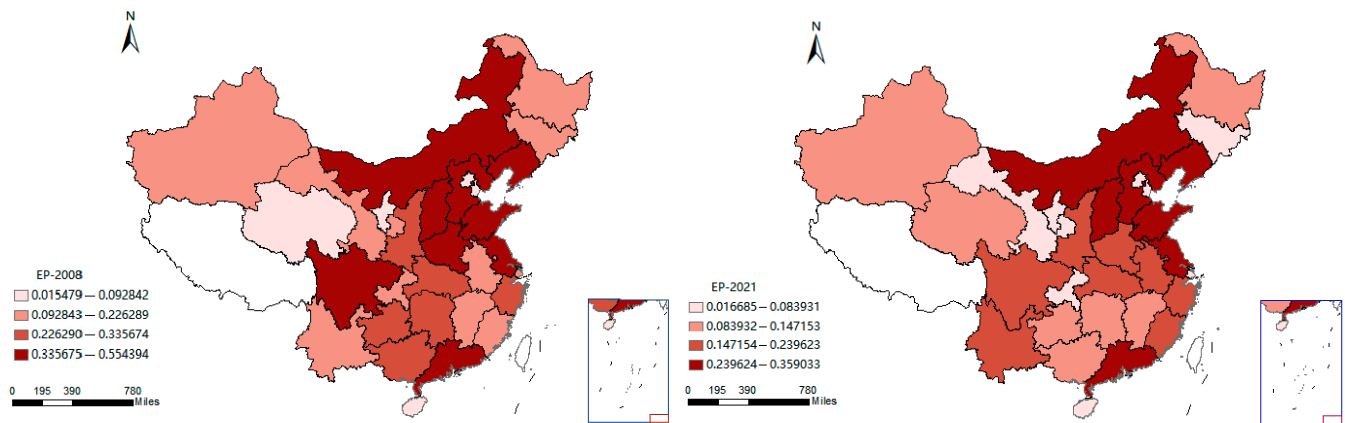


Figure 1. Spatial features of EP in China in 2008 and 2021.

EP varies significantly across different regions of China, influenced by factors like economic development, industrial agglomeration, and energy use. Firstly, the eastern and central regions are economically developed, experiencing rapid industrialization and urbanization that lead to significant resource consumption and pollutant emissions. In contrast, while the western region is also developing quickly, its weaker economic foundation and lower level of industrialization result in relatively less EP. Secondly, the eastern and central regions attract many enterprises due to their favorable geographical locations and traffic conditions. While this agglomeration boosts regional economic development, it also leads to concentrated EP. In contrast, the western region experiences lower industrial concentration and less environmental pressure due to natural conditions and traffic limitations. Finally, the eastern and central regions have high energy demands and traditionally rely on polluting sources like coal, resulting in significant pollutant discharge. In contrast, while the western region has abundant energy resources, it has recently focused more on clean and efficient energy use, leading to relatively lower EP.

6. Empirical Results

6.1. Panel Unit Root Test and Panel Cointegration Test

Before using the SARTP model, it is crucial to verify the stationarity of each variable to prevent pseudo-regression resulting from non-stationary series. To achieve this, we utilize unit root tests, specifically IPS, LLC, Fisher-ADF, and Fisher-PP. According to Table 2, only *ER*, *TECH*, and *IL* satisfy all tests, whereas the remaining variables are determined to be non-stationary. To test for a long-term, stable relationship between variables, we employ the panel cointegration test. Common methods include the Pedroni, Kao, and Westerlund tests. Notably, Panel-ADF and Group-ADF in the Pedroni tests are more accurate for testing short-term data [70]. Thus, we utilize the Pedroni test method for our analysis. As shown in Table 3, there is a long-term co-integration relationship among the variables, allowing them to be used for subsequent modeling and estimation.

Table 2. Panel unit root test results.

Series	IPS	LLC	Fisher—PP	Fisher—ADF
<i>EP</i>	−2.4897 ***	−6.7213 ***	24.8340	19.4746
<i>EGT</i>	−3.7948 ***	−7.8952 ***	21.3451	32.9327
<i>PNGAP</i>	−3.7948 ***	−7.8952 ***	60.2502	85.3873 **
<i>OPEN</i>	−4.0569 ***	−5.0363 ***	54.6920	161.4783 ***
<i>ER</i>	−6.0527 ***	−3.3491 ***	77.1289 *	151.1276 ***
<i>FDI</i>	−3.1249 ***	−7.3726 ***	72.0651	59.0311
<i>TECH</i>	−2.2745 **	−4.1507 ***	87.0748 **	80.4882 **
<i>IA</i>	4.6851	2.5495	349.4668 ***	200.6194 ***
<i>RD</i>	−3.6852 ***	−4.9511 ***	38.9424	80.9641 **
<i>IL</i>	−5.6146 ***	−4.9847 ***	157.2554 ***	80.9527 **
<i>EC</i>	−2.4551 ***	−7.5397 ***	83.9425 **	64.5758

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ (the same below).

Table 3. Panel cointegration test results.

Series	Pedroni Test		Series	Pedroni Test	
	Panel—ADF	Group—ADF		Panel—ADF	Group—ADF
<i>EGT</i>	−3.5518 ***	−3.9369 ***	<i>TECH</i>	−0.1785 *	4.1312 ***
<i>PNGAP</i>	−1.8422 **	−2.2668 **	<i>IA</i>	−1.5611 *	−1.7165 **
<i>OPEN</i>	2.0412 **	1.5860 *	<i>RD</i>	−3.1633 ***	−2.1991 **
<i>ER</i>	2.1070 **	2.2756 **	<i>IL</i>	4.6818 ***	5.6718 ***
<i>FDI</i>	−1.7291 **	−1.9644 **	<i>EC</i>	3.2084 ***	2.7938 ***

6.2. Spatial Correlation Test

Before using the SARTP model, it is essential to test the spatial correlation of EP. We assess this by calculating the global Moran's I [71], with the results shown in Table 4. Moran's I values for EP during the sample period are all positive and mostly significant. This indicates that EP is significantly spatially correlated. Although the correlation pattern has changed, a spatial effect analysis can be carried out in general.

Table 4. Moran's I of EP in China from 2008 to 2021.

Year	Moran's I	Year	Moran's I
2008	0.089	2015	0.121 *
2009	0.090	2016	0.136 *
2010	0.094	2017	0.125 *
2011	0.133 *	2018	0.137 *
2012	0.135 *	2019	0.123 *
2013	0.139 *	2020	0.095
2014	0.128 *	2021	0.137 *

6.3. Estimation Results

Before using the SARTP model, we conduct two key tests. Firstly, we perform the threshold existence test using *EGT* as the threshold variable. The results show $F_1 = 142.3784$ and $p = 0.000$, indicating a significant threshold effect between *EGTs* and EP. Secondly, the threshold number test indicates $F_2 = 0.000$ and $p = 1$, confirming a single threshold. Thus, the model is identified as a two-regime SARTP model. Column (3) of Table 5 presents the estimation results for this model. For comparison, we include the estimated results from the fixed effect (FE) and spatial autoregressive (SAR) models. Notably, the SARTP model has the highest $\bar{R}^2$ among the three models. This indicates that the SARTP model is superior in capturing both spatial spillover and nonlinear threshold

effects compared to the other models. Therefore, we will focus on analyzing the results from the SARTP model. It can be seen from Table 5 that the EGT threshold is 0.0750. The regression coefficient vectors β_1 and β_2 indicate the impact of EGTs and control variables on EP in regime I ($EGT \leq 0.0750$) and regime II ($EGT > 0.0750$), respectively.

Table 5. Estimation results of three models.

Variables	(1) FE	(2) SAR	(3) SARTP	
<i>EGT</i>	1.3795 ***	0.5954 ***	0.1416	0.3799 **
<i>OPEN</i>	−0.0201	−0.0376	−0.1112 **	−0.1124 ***
<i>ER</i>	1.5344	0.8785	0.4575	0.6750
<i>FDI</i>	0.3958	0.2611	0.5475	0.0504
<i>TECH</i>	−1.8343 **	−0.7280 *	−1.4904 ***	−0.3956
<i>IA</i>	0.0728	0.1637	0.1414	−0.0101
<i>RD</i>	−2.4532	−1.6037 **	−2.0811 **	−1.7855 **
<i>IL</i>	−0.1831 **	−0.0655	0.0137	−0.0497
<i>EC</i>	0.0094 **	0.0123 ***	0.0139 ***	0.0157 ***
Threshold value	/	/	$EGT \leq 0.0750$	$EGT > 0.0750$
ρ	/	0.6214 ***	0.5870 ***	
$\bar{R}^2$	0.4273	0.5122	0.9266	

Table 6 displays the mean values of all variables for both regime I and regime II. The EP index in regime II is significantly higher than in regime I, indicating that EP worsens as EGTs rise. Several factors contribute to this issue. First, increasing EGTs often push companies to adopt energy-intensive and high-emission production methods in pursuit of higher output and profits. This approach typically results in significant pollutant emissions, worsening EP. Secondly, while pursuing economic growth, governments and enterprises tend to prioritize economic development over environmental protection and sustainable practices, leading to greater resource consumption and environmental damage. Additionally, achieving these growth targets significantly raises the demand for resources, further intensifying environmental pressure.

Table 6. The average of each variable for regime I and regime II.

Variables	Regime I ($EGT \leq 0.0750$)	Regime II ($EGT > 0.0750$)
<i>EP</i>	0.1952	0.2607
<i>EGT</i>	0.0661	0.1007
<i>OPEN</i>	0.2935	0.2685
<i>ER</i>	0.0028	0.0040
<i>FDI</i>	0.0163	0.0242
<i>TECH</i>	0.0241	0.0190
<i>IA</i>	0.0326	0.0216
<i>RD</i>	0.0231	0.0184
<i>IL</i>	0.0900	0.0542
<i>EC</i>	4.2971	3.3119

As shown in column (3) of Table 5, when the *EGT* exceeds 0.0750, the regression coefficient for the *EGT* rises from 0.1416 to 0.3799, shifting its impact on EP from insignificant to significant. This suggests that higher EGTs notably worsen EP, confirming Hypothesis 1. This may be due to high EGTs leading to excessive resource consumption and environmental damage. Meanwhile, weak government oversight allows enterprises to illegally emit pollutants for profit. Enterprises prioritize short-term economic gains over long-term environmental impact, exacerbating environmental issues.

Furthermore, as EGTs increase, while OPEN can mitigate EP, EC further exacerbates it. Additionally, the mitigating effect of RD on EP diminishes. In regions with lower EGTs, TECH significantly reduces EP. The enhancement of EGTs often accelerates opening up, attracting more foreign investment. The high environmental standards set by foreign-funded enterprises further motivate domestic companies to upgrade their environmental practices and boost market competitiveness. However, economic growth pressures lead to biased resource allocation towards short-term projects, constraining long-term investments like green technology R&D. The conflict between short-term economic interests and long-term sustainable development has led companies and governments to prioritize rapid economic growth over the development of eco-friendly technologies. In contrast, regions with lower EGTs experience less economic pressure, allowing for more rational resource allocation and greater investment in environmental protection infrastructure, effectively reducing EP. It is important to note that the increased EGTs come with a broad expansion of economic activity, leading to a surge in energy demand. To meet the needs of industry, transportation, construction, and other sectors, fossil fuel exploitation has risen significantly, resulting in substantial harmful pollutant emissions during combustion and serious EP.

To evaluate the reliability of these findings, we re-estimate the SARTP model using the adjacency matrix and the economic distance matrix instead of the previously used geographical distance matrix. Table 7 indicates that the model remains divided into two regimes based on the two matrices above using *EGT* as the threshold variable. The coefficient's magnitude and direction for *EGT* are very close to the results in column (3) of Table 5. This indicates that changes in the spatial weight matrix do not alter the interpretation of the research findings. Furthermore, the spatial autocorrelation coefficient ρ is significantly positive under various spatial weight matrices. These findings highlight the robustness of the SARTP model. It is worth noting that educational level (*EDU*) may influence EP by strengthening environmental awareness and promoting the adoption of green technologies. Therefore, we include *EDU* as a control variable in the SARTP model, where *EDU* is defined as the average years of education. Column (3) of Table 7 shows that even after controlling for educational level, high EGTs still significantly worsen EP, confirming the robustness of our findings. Additionally, the impact of educational level on EP is found to be insignificant.

Table 7. Robustness test results.

Variables	SARTP Model					
	(1) Adjacency Matrix		(2) Economic Distance Matrix		(3) Add a Control Variable	
<i>EGT</i>	−0.4663	0.3892 **	0.1550	0.3786 **	−2.3661	0.4894 ***
<i>EDU</i>					0.0092	−0.0085
Control variables	YES	YES	YES	YES	YES	YES
Threshold value	$EGT \leq 0.0700$	$EGT > 0.0700$	$EGT \leq 0.0750$	$EGT > 0.0750$	$EGT \leq 0.0700$	$EGT > 0.0700$
ρ	0.1427 ***		0.5022 ***		0.1418 ***	
$\overline{R}^2$	0.9423		0.9185		0.9436	

The logical starting point of this paper is that in provinces where economic growth targets are set higher, government-led economic development has significantly exacerbated environmental pollution. However, a potential concern is that environmental pollution may not be the result of government intervention but rather driven by market forces. Given that economic growth targets are primarily set by the government, the difference between the actual economic growth rate and the growth target is mainly influenced by market factors. Therefore, this paper constructs two core explanatory variables for a placebo test: the difference between the actual economic growth rate and the economic

growth target (*TARGET1*) and the ratio of the actual economic growth rate to the economic growth target (*TARGET2*). As shown in columns (1) and (2) of Table 8, when the economic growth target (*EGT*) exceeds 0.0800, the coefficients of *TARGET1* and *TARGET2* are both significantly negative at the 1% level. This indicates that in provinces with higher economic growth targets, market-driven economic development significantly reduces environmental pollution. This conclusion is in stark contrast to the baseline regression results, thereby confirming the robustness of the baseline findings.

Table 8. Placebo test results.

Variables	(1) EP		(2) EP	
<i>TARGET1</i>	−0.0419	−0.1107 ***		
<i>TARGET2</i>			−0.0099	−0.1107 ***
<i>OPEN</i>	1.2947	0.1513	1.1771	0.0817
<i>ER</i>	−0.4622	1.7376 ***	−0.4035	1.7195 ***
<i>FDI</i>	−2.8788 ***	−0.0543	−2.7858 ***	−0.0721
<i>TECH</i>	0.0122 ***	−0.0564	0.0133 ***	−0.0007
<i>IA</i>	−0.0739 **	0.7798	−0.0739 **	0.9253
<i>RD</i>	0.0647	−0.9581	0.0967	−1.0086 *
<i>IL</i>	2.0887 ***	−2.3464 ***	2.0712 ***	−2.2706 ***
<i>EC</i>	−0.0226	0.0184 ***	−0.0275	0.0192 ***
ρ	0.5680 ***		0.5631 ***	
Threshold value	$EGT \leq 0.0800$	$EGT > 0.0800$	$EGT \leq 0.0800$	$EGT > 0.0800$
$\bar{R}^2$	0.9267		0.9268	

Notably, the results of the placebo test have important policy implications. On the one hand, properly managing the relationship between the government and the market is a key prerequisite for achieving high-quality development. On the other hand, market-oriented resource allocation is regarded as an effective way to guide various production factors towards green and low-carbon development. Therefore, the government should reduce its intervention in market operations and rely more on market-driven economic mechanisms to promote sustainable green development.

6.4. Heterogeneity Tests

6.4.1. Heterogeneity Based on Geographical Location

Geographical location influences the EP effect of EGTs, as different regions experience varying levels of EP due to disparities in resource distribution, climate conditions, transportation, and policy support. Therefore, we categorize 30 provinces into eastern, central, and western regions based on their geographical locations [72]. The results in Table 9 indicate that as EGTs increase, the EP effect intensifies in the central region, is somewhat alleviated in the western region, and remains insignificant in the eastern region. This indicates that EGTs affect EP differently across regions.

The impact of EGTs on EP varies across different geographical locations, primarily due to the disparities in regional economic development levels and industrial structures. The central region has a high proportion of heavy industry, which generates significant pollutants during production. When EGTs are raised, investment in heavy industry may increase to meet economic goals quickly, leading to greater EP. The economic structure of the western provinces is relatively simple, and, in recent years, more proactive ecological protection measures have been implemented. Even though EGTs have been raised, the lower levels of industrialization have led to a reduction in pollution's impacts. Conversely, the eastern region's early economic development has led to a more optimized industrial structure with complete industrial chains. Industries in the eastern region typically have

higher technical content and added value while causing relatively less environmental harm. The geographical differences reflect the imbalance among provinces in terms of economic development and industrial structure adjustment. These factors collectively influence the varying responses of different regions to the relationship between EGTs and EP.

Table 9. Heterogeneity test results based on geographical location.

Variables	(1) Eastern Provinces		(2) Central Provinces		(3) Western Provinces	
<i>EGT</i>	0.3956	−0.0842	1.2526	1.3261 ***	1.5494 ***	1.2072 ***
<i>OPEN</i>	−0.1209	0.0077	−0.1669	−0.4276 **	−0.6315 ***	−0.1884 **
<i>ER</i>	−3.4331	−1.6166	2.3539	0.2046	0.7987	2.5483 **
<i>FDI</i>	−0.1557	−1.2242 ***	0.2456	2.4822 **	−0.6986	0.4684
<i>TECH</i>	−0.2298	−1.5409	−4.2167 ***	0.8194	−2.4712	−5.6431 ***
<i>IA</i>	1.2384	0.2152	0.6411	2.9876	24.4554 **	20.6378 **
<i>RD</i>	−5.0075 **	−7.1868 ***	5.3784	−4.2059 *	0.7914	1.4032
<i>IL</i>	−0.1904	−0.5974 ***	−0.0524	−0.2000	0.0502	0.0917
<i>EC</i>	−0.0301 **	0.0345 **	0.0133	0.0183	0.0107 **	0.0146 ***
Threshold value	<i>EGT</i> ≤ 0.0750 <i>EGT</i> > 0.0750		<i>EGT</i> ≤ 0.0750 <i>EGT</i> > 0.0750		<i>EGT</i> ≤ 0.0750 <i>EGT</i> > 0.0750	
ρ	0.5316 ***		0.9386 ***		0.3719 ***	
$\bar{R}^2$	0.9484		0.9325		0.8859	

6.4.2. Heterogeneity Based on Population Size

The EP effect of EGTs may relate to regional population size. A larger population exacerbates these effects, as densely populated areas generate more waste and emissions, leading to greater environmental issues. Therefore, we divide the 30 provinces into two groups based on median population. As shown in Table 10, regardless of population size, the EP effect of EGTs diminishes as they increase. However, overall, the EP effect of EGTs is relatively greater in provinces with a large population size.

Table 10. Heterogeneity test results based on population size.

Variables	(1) High Population Size Region		(2) Low Population Size Region	
<i>EGT</i>	3.0918 ***	1.3576 ***	0.7741 **	0.6147 ***
<i>OPEN</i>	−0.0649	−0.0257	−0.0252	−0.0547 *
<i>ER</i>	4.9468	5.8122 **	1.6309	1.0971
<i>FDI</i>	−0.3111	−0.8204 **	0.2375	−0.1215
<i>TECH</i>	1.6095 *	0.3024	−0.5585	−1.1045
<i>IA</i>	5.4967 *	7.5185 **	−1.2439 **	−1.0145
<i>RD</i>	−6.1329 ***	−4.7946 **	−1.0294	0.1112
<i>IL</i>	−0.1241	0.1023	−0.0173	−0.1841 *
<i>EC</i>	0.0341 **	0.0729 ***	0.0073 **	0.0142 ***
Threshold value	<i>EGT</i> ≤ 0.0750 <i>EGT</i> > 0.0750		<i>EGT</i> ≤ 0.0850 <i>EGT</i> > 0.0850	
ρ	0.6155 ***		0.4217 ***	
$\bar{R}^2$	0.8993		0.9452	

The difference in population size leads to varying impacts of EGTs on EP, primarily due to the higher resource demand and pollution emission pressures faced by provinces with larger populations. Provinces with larger populations are generally more industrialized and have concentrated production activities. These activities consume significant resources and emit higher levels of pollutants. Additionally, resource allocation in populous provinces may be distorted by excessive demand for resources. To drive economic growth, governments and enterprises in these provinces often prioritize resources for energy-intensive, high-emission industries at the expense of environmental protection, worsening pollution.

In provinces with smaller populations, the industrial structure is more simplified, with lower resource demand and pollution emissions. Additionally, environmental protection measures in these provinces may be easier to implement, resulting in a smaller impact of EGTs on EP.

6.4.3. Heterogeneity Based on Industrial Structure

The EP effect of EGTs may be linked to regional industrial structure. In areas at early or mid-industrialization stages, the tertiary industry has a low share, with the secondary industry driving economic growth, leading to a more pronounced EP effect. Conversely, in regions with developed economies and a strong tertiary sector, economic growth relies more on technological and service innovation, thereby reducing EP risk. Based on the relationship between the proportion of tertiary industry output value and the sample average from each province during the study period, we categorize the samples into regions with low and high tertiary industry proportions for testing. The results in Table 11 show that the EP effect of EGTs is significantly greater in provinces with a low proportion of tertiary industry, while it is not significant in those with a high proportion.

Table 11. Heterogeneity test results based on industrial structure.

Variables	(1) High Tertiary Industry Proportion Region		(2) Low Tertiary Industry Proportion Region	
EGT	0.2590	0.1094	1.2461 **	0.8021 ***
OPEN	−0.0074	−0.0464	−0.3104 **	−0.1363 *
ER	2.9485	−0.1569	2.3694 *	0.8729
FDI	0.6575	0.1163	−0.2458	0.0161
TECH	−2.1883 ***	−1.3485	3.4490 ***	−0.4193
IA	−0.4926	−0.9485	3.1325	8.9193 ***
RD	−3.6105 ***	−3.3600 ***	−0.1097	−0.0544
IL	−0.0759	−0.3080 **	0.0576	−0.0175
EC	−0.0080	0.0156	0.0076 *	0.0158 ***
Threshold value	EGT ≤ 0.0850		EGT ≤ 0.0750	
	EGT > 0.0850		EGT > 0.0750	
ρ	0.4364 ***		0.9900 ***	
$\bar{R}^2$	0.9423		0.9350	

The difference in industrial structure leads to varying impacts of EGTs on EP, primarily due to the resource consumption characteristics and pollution emission levels of different industries. Manufacturing and heavy industry rely heavily on energy and raw materials. Their production processes involve high energy consumption and significant pollutant emissions. In provinces with a low proportion of the tertiary industry, traditional industries have a more pronounced pollution effect when driving economic growth. In contrast, provinces with a higher proportion of the tertiary industry depend more on the service sector and high-tech industries for economic growth. These sectors use fewer resources and lower pollution emissions through technological innovation and efficiency. In addition, the tertiary industry typically has mature environmental policies and governance systems, allowing for more effective pollution control.

6.5. Further Discussion

When local governments set easily achievable EGTs, they are less likely to distort resource allocation. However, to showcase governance capabilities to the central government, local governments often set ambitious growth targets, resulting in top-down amplification of these economic goals. This behavior can distort resource allocation further and worsen EP caused by economic growth. Based on the analysis above, PNGAP is incorporated into the SARTP model as a threshold variable. First, the threshold existence test yields

$F_1 = 115.7785$, $p = 0.000$, indicating a threshold effect between EGTs and EP. Next, the threshold number test results in $F_2 = -2.3066$, $p = 1$, confirming a single threshold. Thus, the model is identified as a two-regime SARTP model.

In Table 12, column (1) employs the geographical distance matrix to estimate the SARTP model. The findings suggest that when *PNGAP* exceeds 0.0050, the regression coefficient for the *EGT* rises from 0.3611 to 0.4469, shifting their impact on EP from insignificant to significant. This indicates that the top-down amplification of EGTs exacerbates EP caused by pursuing these targets, confirming Hypothesis 2. Column (2) of Table 12 re-estimates the SARTP model using an adjacency matrix instead of the geographical distance matrix. *EGT* coefficients are similar in magnitude and direction to those in column (1), further validating the robustness of the research's conclusions.

Table 12. Estimation results of the SARTP model using *PNGAP* as a threshold variable.

Variables	SARTP Model			
	(1) Geography Distance Matrix		(2) Adjacency Matrix	
<i>EGT</i>	0.3611	0.4469 **	0.0443	0.3942 **
Control variables	Yes	Yes	Yes	Yes
Threshold value	$PNGAP \leq 0.0050$	$PNGAP > 0.0050$	$PNGAP \leq 0.0050$	$PNGAP > 0.0050$
ρ		0.6220 ***		0.1447 ***
$\bar{R}^2$		0.9231		0.9420

This can be attributed to several factors. First, higher-level governments view economic growth as a key performance indicator, pressuring local governments to set excessively high EGTs. Second, to meet high EGTs, local governments often pursue short-term, profit-driven strategies that favor resource-intensive and polluting industries. Additionally, local governments lack effective environmental supervision, leading to insufficient investment in environmental protection and difficulty in curbing violations. These combined factors result in local governments overlooking environmental costs and sustainability, exacerbating EP.

7. Conclusions, Policy Implications, and Limitations

7.1. Conclusions

Using panel data from 30 Chinese provinces, we utilize a SARTP model to explore the EP problem from the perspective of EGTs. The research findings indicate the following. (1) EP has a significant positive spatial spillover effect. A 1% increase in the EP index in adjacent provinces results in a 0.5870% increase in the observing province. (2) For provinces with EGTs above 7.5%, a 1% increase in an EGT results in a 0.3799% increase in the EP index. For provinces with EGTs below 7.5%, the impact of EGTs on EP is not significant. (3) As EGTs increase, openness reduces EP, but the mitigating effect of R&D intensity on EP weakens, and energy consumption exacerbates it. In provinces with low EGTs, technological investment significantly lowers EP. The impact of other control variables on EP is not significant. (4) As EGTs increase, the EP effect intensifies in central provinces, weakens in western provinces, and remains insignificant in eastern provinces. Provinces with larger populations experience greater EP effects from EGTs compared to those with smaller populations. Compared to provinces where the tertiary industry leads, those with a low proportion of it experience significantly greater EP effects from EGTs. (5) The top-down amplification of EGTs exacerbates EP caused by pursuing these targets. When the provincial EGT exceeds the central target by 0.5%, a 1% increase in the EGT results in a 0.4469% increase in the EP index.

7.2. Policy Implications

The policy implications derived from the aforementioned research findings are as follows.

7.2.1. Create a Joint Mechanism for Inter-Provincial EP Prevention and Control and Improve the Dynamic Monitoring Network for Border Pollution

Given the significant trans-regional spillover effects of EP, local governments should establish inter-provincial joint prevention and control mechanisms to foster inter-provincial pollution management communities. Specific measures include the following. First, implement ecological compensation mechanisms and tax differentiation policies to encourage environmentally friendly practices and reduce pollution emissions. Second, create a regional emission trading market to facilitate trading among enterprises, achieving economic and environmental benefits simultaneously. Additionally, local governments must enhance the dynamic monitoring network for border pollution to understand real-time pollution conditions and respond promptly with appropriate measures.

7.2.2. Set Realistic EGTs, Boost Environmental Protection Investment, and Minimize EP

In response to the notable aggravation of EP in provinces where EGTs exceed 7.5%, here are some policy recommendations. On one hand, policymakers should set realistic EGTs and recognize the environmental pressures associated with high economic growth. Local governments must incorporate environmental protection into their economic development plans to avoid prioritizing economic expansion at the expense of the environment. On the other hand, local governments need to boost investment in environmental protection in high-growth provinces and enhance their governance capabilities. This includes improving environmental infrastructure and monitoring systems for timely and accurate assessments of environmental conditions.

7.2.3. Promote Opening Up, Optimize R&D Allocation, Upgrade Energy Structure, and Boost Technological Investment to Reduce EP

Considering the need to weigh the effect of openness, R&D intensity, energy consumption, and technology investment on EP when setting EGTs, local governments and relevant enterprises should implement the following measures. (1) Given that openness significantly reduces EP, local governments should steadfastly promote high-level opening up, expand the scale of imports and exports, and effectively reduce EP. (2) Given the diminishing impact of R&D intensity on reducing EP, relevant enterprises should optimize their R&D resource allocation. They should encourage technological innovation towards green and low-carbon fields to ensure that R&D activities effectively enhance environmental quality. (3) Given that energy consumption significantly aggravates EP, high-energy-consuming enterprises should strictly limit total energy use, accelerate the transformation of their energy structure, promote clean energy adoption, and fundamentally reduce sources of pollution. (4) Given that technology investment significantly reduces EP, local governments should enhance their support for such investments to leverage their role in minimizing pollution.

7.2.4. Differentiated EGTs Should Be Based on Each Province's Geographical Location, Population Size, and Industrial Structure

Given the significant differences in geographical location, population size, and industrial structure across provinces, each province should establish tailored EGTs. (1) Central provinces must enhance environmental supervision, promote green technologies, and optimize industrial structures to minimize EP. (2) Western provinces should enhance ecological protection, promote coordinated regional development, and cultivate characteristic industries to balance economic development with environmental protection. (3) Provinces with larger populations should boost public understanding of environmental conservation

efforts, strengthen environmental regulations, and promote eco-friendly living practices. (4) Provinces with a smaller share of the tertiary industry should adjust their industrial structure, actively develop the tertiary sector, and receive policy support and vocational training.

7.2.5. The Central Government Should Incorporate Environmental Protection into Local Government Performance Assessments and Guide Them to Optimize EGTs

Provincial governments often set overly ambitious EGTs to showcase their governance to the central government, which can result in heightened EP. The central government should set realistic EGTs, considering each province's actual situation and the capacity of resources and the environment. Simultaneously, the central government should incorporate environmental protection into local government performance assessments and reasonably reduce the weight of EGTs. Furthermore, the central government should enhance environmental supervision of local governments, establish an environmental accountability mechanism, promote the green economy, optimize industrial structure, and strengthen resource conservation and recycling. To summarize, the central and local governments should enhance policy coordination to promote the balanced development of the economy and environment, achieve sustainable development goals, and ensure a win-win outcome for economic growth and environmental conservation.

7.3. Limitations

Indeed, this study has certain limitations and requires further exploration in future research. (1) We select wastewater, SO₂, and solid waste as the three pollutants to construct the EP index. Future research can include other pollutants, like PM_{2.5} or CO₂, within the scope of the EP index. (2) The conclusions of this study may have limitations in other countries. Future research can apply the model and analysis methods of this study to other countries. (3) Although the SARTP model and placebo tests are adopted in this paper to alleviate the endogeneity problem, there may still be unobservable confounding factors due to the limitations of the data and the model. On the basis of the SARTP model, future research can consider the spatial error term and serial correlation or add variables like political dynamics and informal governance practices to strengthen the identification and control of unobservable confounding factors so as to further improve the accuracy of the results.

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Appendix A

To measure EP effectively, we select wastewater discharge, SO₂ discharge, and general industrial solid waste production as key indicators. These metrics effectively reflect the

impact of different pollution forms on the environment and provide a scientific basis for assessing EP levels.

Criteria for indicator selection: On one hand, wastewater discharge, SO₂ discharge, and general industrial solid waste production are the primary sources of water, air, and solid waste pollution. On the other hand, these three pollutants are prevalent during China's industrialization and significantly impact the environment. Local governments focus their pollution control efforts on these three pollutants. Therefore, these three pollutants are appropriate indicators for measuring the EP index.

Weight calculation method: We employ the entropy method to objectively determine the weights of each indicator based on data variability. Indicators with greater variability are deemed more important, resulting in higher weights. The process involves first calculating the entropy of each indicator to reflect the distribution of information, then standardizing the entropy values to eliminate dimensional differences, and, finally, calculating the weights of each indicator based on the standardized entropy values to obtain the final composite EP index.

Rationale for the method: The entropy method avoids subjective bias, ensuring that weight allocation is based on the inherent variability of the data, thereby guaranteeing the objectivity and scientific rigor of EP assessment.

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