

Retraction

Retracted: Environmental Regulation, Financial Resource Allocation, and Regional Green Technology Innovation Efficiency

Discrete Dynamics in Nature and Society

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] Q. Bao and H. Chai, "Environmental Regulation, Financial Resource Allocation, and Regional Green Technology Innovation Efficiency," *Discrete Dynamics in Nature and Society*, vol. 2022, Article ID 7415769, 11 pages, 2022.

Research Article

Environmental Regulation, Financial Resource Allocation, and Regional Green Technology Innovation Efficiency

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This paper empirically studies the environmental regulation, financial resource allocation, and regional green technology innovation efficiency by using provincial panel data from 2005 to 2019. The results show that the cost-input environmental regulation is negatively correlated with the efficiency of regional green technology innovation, while the government-subsidized environmental regulation is positively correlated with the efficiency of regional green technology innovation. The mechanism test shows that the cost-input environmental regulation reduces the efficiency of green technology innovation by restraining the allocation of financial resources, while the government-subsidized environmental regulation lifts the efficiency of green technology innovation by improving the allocation of financial resources. As far as different regions are concerned, the cost-input environmental regulation has a significant inhibitory effect on the eastern and central regions, while the government-subsidized environmental regulation has a significant improvement effect on the central and western regions.

1. Introduction

Since the reform and opening up, China's economy has experienced a period of rapid development driven by a crude growth model, but this has also led to problems such as environmental pollution and waste of resources, and this unsustainable and inefficient growth approach has gradually highlighted the importance of green technology innovation. Green technology innovation, as an important prerequisite for balancing China's economic growth and environmental issues, has become a major driving force for China's green economic development and transformation. Green technology innovation cannot be achieved through a single market mechanism due to the negative externalities of the ecological environment and the public goods attribute of natural resources, and needs to be led by scientific and effective environmental regulation. Therefore, it is important for the quality development of China's economy to play a positive role in environmental regulation to enhance the efficiency of green technology innovation and reduce environmental pollution and resource waste in the process of

economic development. To this end, the study of the relationship between environmental regulation and the efficiency of green technology innovation is of great significance in understanding green technology innovation, solving the problem of environmental pollution in China's economic development, and continuously transforming the green economic development model.

2. Literature Review

Environmental regulation has an irreplaceable impact on green technological innovation and even economic development. Traditional economic growth theory suggests that the impact of environmental pollution and environmental policy is not significant, but in the context of sustainable development policies and environmental development, endogenous growth theory is gradually becoming a new accelerating force for economic development. Some scholars have relied on the framework of endogenous growth theory to study whether environmental policies can achieve a symbiosis between pollution control and enhancing

economic development. Reference [1], while enhancing the efficiency of technological innovation through resource allocation and thus transforming economic development, has become an important way for the market to adapt to changes in environmental regulation, as well as a source and driver of green and sustainable development in China. Jie et al. have a correlation and also argue that environmental innovation is influenced by environmental regulation. Therefore, they construct a total factor productivity index for energy and carbon emissions, and in the final results show that environmental regulation has a significant positive impact on environmental innovation as well as environmental performance [2]. Zhou et al. use the Yangtze River Delta in China as the research environment to analyze the relationship between environmental regulation and innovation, and finally argue that the impact of environmental regulation on the impact of environmental regulation on innovation in the Yangtze River Delta region shows an inverted U-shape, and some policy recommendations are made to promote regional economic development [3]. Daming You et al. analyze the impact of environmental regulation on corporate eco-innovation and point out in their study that the impact of environmental regulation on corporate eco-innovation is constrained by China's fiscal system, arguing that the decentralization or otherwise of China's fiscal system can be a factor inhibiting or promoting the economic development[4].

The famous Porter Hypothesis of the 1990s argues from a dynamic perspective that reasonable environmental regulation has a compensatory effect on innovation, i.e., an appropriate intensity of environmental regulation can compensate for the cost of regulation, thus promoting technological innovation and enabling the industry in which the firm is located to gradually achieve Pareto improvements [5]. The green economy has gradually become the main direction of technological innovation adjustment, with "green" as the core and technological innovation upgraded to "green technological innovation," resulting in a number of measures of green technological innovation efficiency, among which, single indicator measures, stochastic frontier analysis (SFA), and data envelopment analysis (DEA) are the main ones. [6] Single indicator measures are based on the results of green technology innovation and use a single indicator of green technology patents to measure changes in the efficiency of green technology innovation [7]. SV Avilés-Sacoto et al. propose to use DEA to assess the efficiency of green innovation of enterprises and to analyze the relative efficiency of enterprises through inter-firm comparison [8]. Jiyoung et al. analyzed the innovation efficiency of firms in the Korean region and used DEA to assess and compare the global Malmquist productivity of firms and concluded that the innovation efficiency generated by DEA can lead to appropriate cooperation strategies between firms, which is important for the development of innovation in the market Significance [9]. Tziogkidis et al. assess the efficiency of green innovation in different countries, considering the economic environment of different countries, demonstrating a large asymmetry between innovation efficiency

and sensitivity, pointing out the diversity of innovation in different countries and suggesting more informed decisions [10].

In summary, in recent years, a large number of studies on environmental regulation have pointed out its impact on environmental innovation but have not explored the specific efficiency of green innovation in depth. As for the innovation development of green innovation technology, most studies only assess the current status of green innovation efficiency through DEA but do not deeply analyze the influencing factors and mechanisms that affect the efficiency of green innovation technology. In this regard, the study starts from the analysis of the current situation of environmental regulation, proposes hypotheses on the efficiency of green technology innovation, and analyses the mechanisms affecting the efficiency of green technology innovation.

3. Empirical Analysis

3.1. Theoretical Mechanism and Research Hypothesis.

Different scholars have analyzed environmental regulation and green technology innovation from different angles. Based on the static point of view, the neo-classical economics school thinks that environmental regulation can increase the production cost of enterprises and reduce the innovation ability and market competitiveness of enterprises by internalizing the negative externality of the environment, that is, "following the cost effect" [11]. From a dynamic point of view, reasonable environmental regulations will encourage enterprises to choose emission reduction technologies and equipment and improve their operating performance. The resulting "innovation compensation" may reduce or even offset the "compliance cost," thus realizing the double dividend of pollution reduction and productivity improvement [12]. However, there are many differences in the time sequence and intensity of "compliance cost" and "innovation compensation," which leads to different measurement methods of environmental regulations. Therefore, the implementation effect of environmental regulations is uncertain. With the increasing requirements of environmental quality and sustainable development, the research on environmental regulation and green technology innovation efficiency has gradually become the focus, mainly including nonlinear threshold effect and spatial spillover effect of environmental regulation [13]. At the same time, with the continuous enrichment of measurement tools and basic data, existing researches have gradually turned to the discussion of performance evaluation of green technological innovation and its influencing factors. On this basis, the spatial characteristics of green technological innovation diffusion are analyzed. With the increasingly close inter-regional relations, the green technology diffusion and spillover have attracted scholars' attention, and spatial factors are gradually brought into the framework of influencing factors analysis [14]. Most studies evaluate the green technology innovation ability from three dimensions including enterprises, industries, and regions [15]. Especially at the regional level, the measurement unit of green

technology innovation capability is mainly based on the provincial scale. Most conclusions show that environmental regulations are closely related to the performance of regional green technology innovation, and there is certain heterogeneity in the eastern, central, and western regions [16].

Hypothesis 1. Environmental regulations will have a significant impact on the efficiency of green technology innovation.

Hypothesis 2. There are significant differences in the efficiency of green technology innovation among different regions.

Environmental regulation has a direct impact on the efficiency of green technology innovation, but it also has an indirect impact through certain factors. As environmental regulations will increase enterprises' expenditure on pollution control and investment in new technology research and development, the pursuit of green development requires financial institutions to reduce or even limit the flow of resources to highly polluting industries and enterprises in the process of resource allocation. Environmental regulations can identify enterprises with large potential output for financial institutions and optimize their resource allocation efficiency [17–19]. Therefore, reasonable environmental regulation combined with rational allocation of financial resources can achieve “win-win” between green economy and technological innovation. In addition, some studies have shown that financial deepening and financial structure optimization can promote the improvement of technical efficiency, but their effects on technological progress are inconsistent [20]. On the one hand, the promotion effect of financial resource allocation on productivity is negative, which weakens innovation and technological progress; on the other hand, the promotion effect of financial resource allocation on productivity is positive, which strengthens the improvement of resource allocation efficiency [21]. Some studies have also pointed out that enterprises may continue to produce products with high pollution and energy consumption after obtaining the allocation of financial resources, which will increase the emissions of carbon dioxide and sulfur dioxide, leading to environmental pollution and even “herding effect” [22] and thereby affect the efficiency of regional green technology innovation.

Hypothesis 3. Environmental regulation affects the efficiency of green technology innovation through the allocation of financial resources.

To sum up, under the background of China attaching increasing attention to the environment and pollution prevention and control, the development of regional green technology innovation efficiency is not unique. Environmental regulations have played an indispensable role in its evolution, and the relationship between them has become increasingly closer. As a consensus, the concept of green development is bound to be influenced by environmental regulations and other factors. Scholars have carried out relevant research from different angles, but there is little research on the relationship among them. Compared with the existing literature, the marginal contributions of this paper are as follows: (1) in terms of research data, both cost input and government subsidy are adopted to measure the level of environmental regulation to explore its influence on the efficiency of green technology innovation. At the same time, financial resource allocation is used as an intermediary variable to test the channels affecting the efficiency of green technology innovation, which can more comprehensively measure how environmental regulation plays a role in the efficiency of green technology innovation through financial resource allocation. (2) In terms of research methods, the measurement of green technology innovation efficiency in existing literature is referred. Taking industrial “three wastes” as unexpected output, Super-SBM model is used to better reflect the change of green technology innovation efficiency, and at the same time, nonlinear influence expansion analysis is used. The relationship between environmental regulation and green technology innovation efficiency and its mechanism are discussed at a deeper level, and regional analysis is made, providing references for the development of regional economies in China in a greener and more optimized direction under the background of financial resource allocation.

3.2. Model Setting. All variables are interpreted uniformly, as shown in Table 1.

To test the influence of environmental regulations on the efficiency of regional green technology innovation, this paper sets the following benchmark models by adopting the regional and temporal double-control fixed effect panel model:

$$\text{rgtie}_{it} = \alpha + \beta \text{ger}_{it} + \gamma gX_{it} + \sum_{i=1}^{30} \phi_i \text{gstate_dum}_i + \sum_{t=1}^{15} \phi_t \text{gyear_dum}_t + \mu_{it}, \quad (1)$$

rgtie_{it} in the above model, as the explained variable of this paper, is used to describe the regional green technology innovation efficiency of i province in the t year, and the specific calculation method will be explained in detail later. The explanatory variable indicates the environmental regulation level of i province in the t year. When describing the

environmental regulation level, this paper considers that since the 18th National Congress, the ecological civilization construction has been raised to the level of national construction through the “five-in-one” general layout. On the one hand, the government has strengthened environmental regulation, formulated relevant laws and regulations,

TABLE 1: Variable interpretation.

| Variable | Interpretation |
|----------------|-----------------------------|
| X_{nt} | Control variable set |
| α | Regression coefficient |
| β | Investment proportion |
| er_{nt} | Core explanatory variables |
| γ | Weight value |
| n | Number of regions |
| t | Number of years |
| ϕ | Investment |
| $state_dum_n$ | Enterprise investment |
| $year_dum_t$ | Annual investment |
| μ_{nt} | Random factors |
| x | Investment |
| y | Produce |
| m | Number of input indicators |
| s | Number of output indicators |
| k | Production period |
| i | Input decision unit |
| r | Output decision-making unit |
| s_i^- | Input slack |
| s_r^+ | Output slack |
| λ_j | Weight vector |

strengthened environmental punishment measures, and invested a lot of money in ecological environment governance; on the other hand, the government strongly subsidizes enterprises through environmental protection expenditure, and provides support for environmental protection R&D expenses. The former can be understood as cost-input environmental regulation (lner), which is measured by the ratio of industrial pollution control investment to total industrial output value, while the latter can be understood as government-subsidized environmental regulation (environ), which is measured by the proportion of environmental protection expenditure in fiscal expenditure.

X_{it} represents the set of control variables to be included in a unified way, including R&D intensity proxy index (rdgdp) of R&D investment of i province in the t year as the share of GDP; the index ins of technology market development degree expressed by the ratio of technology market turnover and industrial added value of i province in the t year (rdgdp); industrial structure index (ins) is measured by the ratio of the added value of the second and third industries of i province in the first year; opening degree index (open) is measured by the proportion of foreign enterprises' import and export of i province to GDP in the first year; index of urbanization speed is expressed by the proportion of urbanization of i province in period t (urban).

3.3. Measurement of Efficiency of Green Technology Innovation. Referring to the measures of green technology innovation efficiency constructed by scholars in existing literature, this paper takes the industrial "three wastes" as unexpected output, and uses Super-SBM model to better reflect the change of China's green technology innovation efficiency:

$$p^* = \min \frac{1 + 1/m \sum_{i=1}^m s_i^- / x_{ik}}{1 - 1/s \sum_{r=1}^s s_r^+ / y_{rk}},$$

$$\text{s.t. } \sum_{j=1, j \neq k}^n x_{ij} \lambda_j - s_i^- x_{ij} \quad (i = 1, 2, \dots, m),$$

$$\sum_{j=1, j \neq k}^n y_{rj} \lambda_j + s_r^+ y_{rj} \quad (r = 1, 2, \dots, s),$$

$$\lambda_j > 0, \quad j = 1, 2, \dots, n \quad (j \neq k), \quad s_i^- > 0, \quad s_r^+ > 0,$$
(2)

wherein p^* is the efficiency value of green technology innovation; x and y are input and output elements, respectively; m and s are the number of input and output indicators, respectively; k represents the production period; i and r are the decision-making units of input and output, respectively; s_i^- and s_r^+ are the slack of input and output, respectively; and λ_j is the weight vector. When $p^* \geq 1$, the production decision-making unit is relatively effective; when $p^* < 1$, the relative ineffectiveness and efficiency loss of production decision-making units are evaluated, and the efficiency of green technology innovation are improved by optimizing input, expected output, and unexpected output.

3.4. Descriptive Statistics of Data Sources and Variables. This paper mainly uses the panel data of 30 provinces (municipalities and autonomous regions) in China from 2005 to 2019 for empirical analysis. The data mainly come from China Industrial Statistics Yearbook, China Environment Yearbook, China Statistics Yearbook, China Energy Statistics Yearbook, provincial statistical yearbooks, etc. Tibet has been excluded due to many missing data.

4. Empirical Result Analysis

4.1. Benchmark Regression Test. Table 1 reports the estimated results of environmental regulation intensity index obtained by two different measurement methods on the efficiency of regional green technology innovation. From Tables 2 and 3, it can be found that the cost-input environmental regulation plays a restraining role in influencing the efficiency of regional green technology innovation, and the conclusion is consistent from perspectives such as comprehensive efficiency, scale efficiency, and pure technical efficiency. It is not difficult to find from the regression results that the cost-controlled environmental regulations restrict the production and operation of enterprises from many aspects. The enterprises themselves are not motivated to make self-innovation and improve the production process, and their ability to reduce production pollution emissions is weak, which leads to the slow improvement and even a downward trend of their own green technology innovation efficiency.

However, the tests from (4) to (6) show that government-subsidized environmental regulations play an improving role in influencing the efficiency of regional green technology innovation, and the conclusions are consistent

TABLE 2: Document analysis.

| Literature | Primary coverage | Problem |
|----------------------|---|---|
| Jie [2] | Building total factor productivity index of energy and carbon emissions | No in-depth analysis of green innovation under environmental regulation |
| Zhou [3] | The relationship between environmental regulation and innovative development in the Yangtze River Delta | |
| Daming You [4] | The impact of China's financial system on environmental regulation | |
| SV Avilés-Sacoto [8] | DEA evaluation of enterprise green innovation efficiency | The influencing factors of green innovation efficiency have not been analyzed |
| Jiyoung [9] | Analyze the impact of enterprise innovation on the market | |
| Tziogkidis [10] | Discuss the efficiency of green technology innovation in different countries | |
| This study | Analyze the impact mechanism of environmental regulation on Green Innovation | — |

TABLE 3: Descriptive statistics of variables.

| Variable | Variable definition | Average | Standard deviation | Min | Max |
|----------|--|---------|--------------------|-------|--------|
| TE | Comprehensive efficiency | 0.673 | 0.153 | 0.498 | 1.312 |
| PTE | Pure technical efficiency | 0.903 | 0.162 | 0.532 | 1.302 |
| SE | Scale efficiency | 0.794 | 0.156 | 0.201 | 1.000 |
| lner | Cost-input environmental regulation index | 3.385 | 0.821 | 1.289 | 5.701 |
| squ_lner | Cost-input environmental regulation index square term | 12.678 | 5.163 | 1.596 | 31.597 |
| environ | Government-subsidized environmental regulation index | 0.054 | 0.031 | 0.012 | 0.173 |
| rdgdp | R&D intensity proxy index | 1.387 | 1.139 | 0.221 | 6.179 |
| tel | Technical turnover intensity index | 0.045 | 0.082 | 0.008 | 0.652 |
| ins | Industrial structure proxy index | 1.134 | 0.306 | 0.258 | 1.965 |
| open | Index of openness of import and export foreign enterprises | 0.147 | 0.203 | 0.034 | 1.689 |
| urban | Proxy index of urbanization degree | 0.607 | 0.182 | 0.215 | 0.763 |

from perspectives including comprehensive efficiency, scale efficiency, and pure technical efficiency. Seen from the regression results, the government-subsidized environmental regulations can promote the production and operation of enterprises from the perspective of subsidies or production costs, and the enterprises' self-innovation, motivation to improve the production process, cooperation with supervision, and ability to reduce production pollution emissions can be improved by cost improvement or external environment improvement, thus resulting in the improvement of their own green technology innovation efficiency. The two environmental regulation indicators are explained from two opposite directions, which verify the robustness of this conclusion.

Seen from the regression results of control variables, the control variables listed in this paper do not change the influence on the efficiency of regional green technology innovation with the measurement of relevant environmental regulation indicators. From the index of R&D innovation intensity (rdgdp), it can be seen that the influence on pure technical efficiency, comprehensive efficiency, and scale efficiency is significantly promoted. The regression result is the same as the influence of regional technology market maturity (tel) on regional green technology innovation efficiency, which indicates that the R&D intensity or technology market development degree of a region will play a very important role in promoting its green technology innovation efficiency. From the perspective of industrial structure (ins), it is found that the influence of high

secondary industrial structure on regional green innovation efficiency is restrained, and the influence of industrial structure variables on regional green innovation efficiency is not very significant. At the same time, it is also concluded that both the degree of external development (open) and the degree of urbanization (urban) of a region can restrain the influence of regional green innovation efficiency.

4.2. *Nonlinear Influence Expansion Analysis.* From the previous analysis, it is concluded that the cost-input environmental regulation plays a restraining role in influencing the efficiency of regional green technology innovation, while the government-subsidized environmental regulation plays an improving role in influencing the efficiency of regional green technology innovation. However, further thinking will raise such questions as to whether the efficiency of green technology innovation in areas affected by environmental regulations is nonlinear, whether there is an inflection point or threshold, and whether relevant conclusions will change after crossing the inflection point. Therefore, this paper introduces the quadratic terms of two kinds of environmental regulations into the model to explore whether this nonlinear influence exists.

$$\begin{aligned}
 \text{rgtie}_{it} = & \alpha + \beta_1 \text{ger}_{it} + \beta_2 \text{gsqu}_{er_{it}} + \gamma gX_{it} \\
 & + \sum_{i=1}^{30} \phi_i \text{gstate_dum}_i + \sum_{t=1}^{15} \phi_t \text{gyear_dum}_t + \mu_{it}.
 \end{aligned} \tag{3}$$

The empirical results show that environmental regulations have a nonlinear influence on the efficiency of regional green technology innovation. Specifically, cost-input environmental regulation has a positive U-shaped impact on the efficiency of regional green technology innovation; the government-subsidized environmental regulation has an inverted U-shaped impact on the efficiency of regional green technology innovation. From the further analysis of relevant inflection points, we can calculate that 95% of the samples are on the left side of the inflection point. That is, the cost-input environmental regulation is in a state of inhibiting the efficiency of regional green technology innovation, while the government-subsidized environmental regulation is in a state of “climbing” improvement, which just confirms the regression results of the benchmark model.

4.3. Analysis of Regional Heterogeneity. This paper takes into account the fact that the control indicators of environmental regulation in the benchmark model have the same influence on regional green innovation efficiency measured by scale efficiency, pure technical efficiency, and comprehensive efficiency. In further analysis, by splitting the samples, we consider what changes will the environmental regulations bring to the efficiency of regional green innovation in different regions? From the regression results in Tables 6 and 7, we can see that the cost-input environmental regulation has obvious inhibitory effect on the eastern and central regions, and its positive U-shaped influence in the eastern and central regions has not changed due to subsamples. Government-subsidized environmental regulation has obvious improvement effect on the central and western regions, and its inverted U-shaped influence on the efficiency of green innovation in the central and western regions has not changed.

4.4. Analysis of Influence Mechanism. Through the previous analysis, it is found that the influence of environmental regulation on the efficiency of regional green technology innovation varies with different measurement methods of environmental regulation. However, we cannot help asking, what is the path of environmental regulation’s influence on the efficiency of regional green technology innovation? What role does this financial resource allocation play, and whether environmental regulations will affect the regional financial resource allocation, thus affecting the local green technology innovation efficiency? Next, this paper introduces the allocation of financial resources into the model through the intermediary model formulas (4)–(6), and uses the existing literature to measure the allocation of regional financial resources for reference. Besides, it standardizes the variables of regional financial resources allocation. To further explore the impact mechanism of environmental regulation on regional green technology innovation efficiency, we firstly construct formula (4), aiming to investigate the overall influence of environmental regulations on the efficiency of regional green technology innovation, which is the same as the benchmark. Secondly, we construct formula (5), aiming to investigate whether environmental regulations have an impact on the allocation of regional financial

resources. Finally, on the basis of formula (4), the intermediary variable is introduced into the model to test whether environmental regulation affects the efficiency of regional green technology innovation by influencing the allocation of financial resources, and formula (6) is constructed at the same time.

$$\begin{aligned} \text{rgtie}_{it} &= \alpha + \beta \text{ger}_{it} + \gamma gX_{it} \\ &+ \sum_{i=1}^{30} \phi_i g\text{state_dum}_i + \sum_{t=1}^{15} \phi_t g\text{year_dum}_t + \mu_{it}, \end{aligned} \quad (4)$$

$$\begin{aligned} \text{finadd_sta}_{it} &= \alpha + \beta \text{ger}_{it} + \gamma gX_{it} \\ &+ \sum_{i=1}^{30} \phi_i g\text{state_dum}_i + \sum_{t=1}^{15} \phi_t g\text{year_dum}_t + \mu_{it}, \end{aligned} \quad (5)$$

$$\begin{aligned} \text{rgtie}_{it} &= \alpha + \beta \text{ger}_{it} + \phi g\text{finadd_sta}_{it} + \gamma gX_{it} \\ &+ \sum_{i=1}^{30} \phi_i g\text{state_dum}_i + \sum_{t=1}^{15} \phi_t g\text{year_dum}_t + \mu_{it}. \end{aligned} \quad (6)$$

From the regression results of the intermediary mechanism test in Table 8, we can see that the improvement of the allocation of financial resources in a region can significantly promote the efficiency of green technology innovation. However, the cost-input environmental regulation plays a certain role in restraining the local financial resource allocation, while the government-subsidized environmental regulation, on the contrary, improves the local financial resource allocation. This also explains why the cost-input environmental regulation can restrain the local green technology innovation efficiency, while the government-subsidized environmental regulation is easy to improve the local green technology innovation efficiency. By observing the significance and symbols of related variables, we can find that some intermediary effects of environmental regulations, through the allocation of financial resources, affect the efficiency of local green technology innovation.

4.5. Robustness and Endogenous Test. Table 9 (1) and (2) are listed as robustness tests, and the regression is conducted after removing 5% outliers before and after the core explanatory variables of cost-input environmental regulation (lner) and government-subsidized environmental regulation (environ), and the results are consistent with the benchmark model test. (3) and (4) are listed as endogenous tests, and the lag period of the explained variable (LTE) is added to the original model for systematic GMM test. The results show that, after correcting the endogenous problems of the model, the cost-input environmental regulation inhibits the regional green technology innovation efficiency, while the government-subsidized environmental regulation promotes the regional green technology innovation efficiency.

4.6. Discussion. The development of green technological innovation is a common trend in current international development, and in the development of innovation in

TABLE 4: Estimated results of benchmark model.

| Variables | Cost-input environmental regulation | | | Government-subsidized environmental regulation | | |
|-------------------|-------------------------------------|-----------------------|-----------------------|--|----------------------|-----------------------|
| | (1) TE | (2) PTE | (3) SE | (4) TE | (5) PTE | (6) SE |
| lner | -0.023 *** (-2.309) | -0.239 ** (-1.990) | -0.012 * (-1.749) | | | |
| environ | | | | 1.177 *** (2.785) | 3.252 ** (2.458) | 0.115 *** (3.397) |
| rdgdp | 0.075 *** (2.899) | 0.077 ** (2.255) | 0.037 ** (2.088) | 0.087 *** (3.328) | 0.102 ** (2.331) | 0.036 ** (2.013) |
| tel | 0.727 *** (5.067) | 0.375 *** (3.225) | 0.090 * (1.914) | 0.700 *** (4.869) | 0.447 *** (4.028) | 0.105 ** (2.056) |
| ins | -0.071 ** (-2.450) | -0.249 (-0.733) | -0.008 (-0.427) | -0.023 ** (-2.667) | -0.156 (-0.443) | -0.002 (-0.114) |
| open | -0.092 * (-1.934) | -0.052 (-0.094) | -0.026 (-0.818) | -0.105 ** (-2.251) | -0.223 (-0.407) | -0.017 (-0.553) |
| urban | -0.593 *** (-4.247) | -3.870 ** (-2.389) | -0.089 (-0.929) | -0.110 (-0.598) | -3.691 * (-1.716) | -0.063 (-0.498) |
| Constant | 1.222 *** (11.966) | 3.931 *** (3.318) | 1.025 *** (14.626) | 0.806 *** (6.887) | 3.006 ** (2.197) | 0.966 *** (11.940) |
| Observed value | 450 | 450 | 450 | 450 | 450 | 450 |
| R ² | 0.529 | 0.319 | 0.247 | 0.551 | 0.311 | 0.240 |
| Regional quantity | 30 | 30 | 30 | 30 | 30 | 30 |
| Control year | YES | YES | YES | YES | YES | YES |
| Control area | YES | YES | YES | YES | YES | YES |

Note. ***, **, and * represent being significant at the level of 1%, 5%, and 10%, respectively. *t* value is shown in brackets, same as that in Tables 3 to Table 7.

TABLE 5: Estimated results of non-linear effects.

| Variables | Cost-input environmental regulation | | | Government-subsidized environmental regulation | | |
|-------------------|-------------------------------------|------------------------|----------------------|--|-------------------------|-------------------------|
| | (1) TE | (2) PTE | (3) SE | (4) TE | (5) PTE | (6) SE |
| lner | -0.041 *** (-3.691) | -0.197 *** (-3.280) | -0.058 * (-1.809) | | | |
| squ_lner | 0.004 *** (3.301) | 0.024 *** (3.630) | 0.010 * (1.734) | | | |
| environ | | | | 4.189 *** (3.791) | 3.077 *** (3.082) | 3.195 *** (4.256) |
| squ_environ | | | | -22.340 *** (-2.945) | -22.113 *** (-3.358) | -24.560 *** (-4.766) |
| rdgdp | 0.076 *** (2.908) | 0.105 *** (3.344) | 0.032 * (1.815) | 0.090 *** (3.469) | 0.098 *** (3.317) | 0.039 ** (2.246) |
| tel | 0.728 *** (5.067) | 0.399 ** (2.240) | 0.086 *** (3.876) | 0.635 *** (4.410) | 0.140 *** (3.082) | 0.034 *** (3.348) |
| ins | -0.072 ** (-2.457) | -0.241 (-0.708) | -0.007 (-0.362) | -0.024 (-0.806) | -0.158 (-0.446) | -0.003 (-0.169) |
| open | -0.093 * (-1.949) | -0.027 (-0.049) | -0.030 (-0.940) | -0.100 ** (-2.157) | -0.215 ** (-2.392) | -0.023 ** (-2.750) |
| urban | -0.590 *** (-4.210) | -3.943 ** (-2.426) | -0.101 (-1.054) | -0.024 (-0.128) | -3.498 (-1.576) | -0.084 (-0.660) |
| Constant | 1.252 *** (8.803) | 3.209 * (1.946) | 0.908 *** (9.336) | 0.671 *** (5.382) | 2.812 * (1.909) | 0.817 *** (9.641) |
| Observed value | 450 | 450 | 450 | 450 | 450 | 450 |
| R ² | 0.559 | 0.330 | 0.241 | 0.590 | 0.333 | 0.210 |
| Regional quantity | 30 | 30 | 30 | 30 | 30 | 30 |
| Control year | YES | YES | YES | YES | YES | YES |
| Control area | YES | YES | YES | YES | YES | YES |

China, green development has gradually become an important goal for market development. According to existing studies, the allocation of financial resources under

environmental regulation has a certain influence on the development of green technological innovation, but the correlation between environmental regulation and green

TABLE 6: Estimated results of regional heterogeneity of cost-input environmental regulation.

| Variables | Eastern region | | Central region | | Western region | |
|-------------------|----------------------|----------------------|------------------------|------------------------|------------------------|------------------------|
| | (1) TE | (2) TE | (3) TE | (4) TE | (5) TE | (6) TE |
| lner | -0.027 * (-1.777) | -0.110 * (-1.853) | -0.041 ** (-2.559) | -0.076 ** (-2.642) | -0.016 (-1.011) | -0.018 (-0.170) |
| squ_lner | | 0.012 * (1.844) | | 0.018 * (1.717) | | 0.001 (0.025) |
| rdgdp | 0.128 *** (2.640) | 0.134 *** (2.709) | 0.038 (0.802) | 0.036 (0.753) | 0.003 (0.056) | 0.003 (0.053) |
| tel | 0.795 *** (3.987) | 0.803 *** (4.012) | 0.791 (1.408) | 0.796 (1.422) | 1.145 * (1.945) | 1.147 * (1.915) |
| ins | -0.188 * (-1.876) | -0.186 * (-1.854) | -0.038 (-1.077) | -0.040 (-1.121) | -0.034 (-0.780) | -0.034 (-0.777) |
| open | -0.073 (-0.973) | -0.079 (-1.040) | 0.820 ** (2.138) | 0.811 ** (2.123) | -0.204 (-0.473) | -0.209 (-0.440) |
| urban | -0.251 (-0.618) | -0.202 (-0.486) | -0.951 *** (-3.361) | -1.008 *** (-3.532) | -0.796 *** (-3.479) | -0.797 *** (-3.419) |
| Constant | 1.440 *** (3.929) | 1.549 *** (3.829) | 1.243 *** (7.291) | 1.093 *** (5.359) | 1.016 *** (7.622) | 1.022 *** (3.894) |
| Observed value | 165 | 165 | 120 | 120 | 165 | 165 |
| R ² | 0.340 | 0.342 | 0.397 | 0.406 | 0.238 | 0.238 |
| Regional quantity | 11 | 11 | 8 | 8 | 11 | 11 |
| Control year | YES | YES | YES | YES | YES | YES |
| Control area | YES | YES | YES | YES | YES | YES |

TABLE 7: Estimated results of regional heterogeneity of government-subsidized environmental regulations.

| Variables | Eastern region | | Central region | | Western region | |
|-------------------|----------------------|----------------------|----------------------|-------------------------|----------------------|------------------------|
| | (1) TE | (2) TE | (3) TE | (4) TE | (5) TE | (6) TE |
| environ | 2.875 (1.236) | 5.728 (1.394) | 1.334 ** (2.250) | 6.971 *** (3.600) | 0.396 * (1.711) | 2.188 ** (2.233) |
| squ_environ | | -8.112 (-0.731) | | -52.526 *** (-3.046) | | -11.187 ** (-2.064) |
| rdgdp | 0.150 *** (3.098) | 0.157 *** (3.173) | 0.062 (1.318) | 0.060 (1.331) | 0.006 (0.094) | 0.002 (0.003) |
| tel | 0.686 *** (3.326) | 0.713 *** (3.398) | 0.669 (1.171) | 0.870 (1.568) | 1.105 * (1.879) | 0.986 * (1.746) |
| ins | -0.127 (-1.312) | -0.129 (-1.330) | 0.014 (0.451) | 0.027 (0.891) | -0.013 (-0.266) | -0.015 (-0.313) |
| open | -0.112 (-1.553) | -0.121 (-1.651) | 0.632 * (1.797) | 0.668 * (1.751) | -0.152 (-0.356) | -0.134 (-0.315) |
| urban | -0.307 (-0.731) | -0.267 (-0.630) | -0.302 (-1.097) | -0.153 (-0.569) | -0.587 * (-1.972) | -0.423 * (-1.863) |
| Constant | 0.913 ** (2.577) | 0.912 ** (2.570) | 0.713 *** (5.303) | 0.495 *** (3.353) | 0.818 *** (5.014) | 0.705 *** (3.623) |
| Observed value | 165 | 165 | 120 | 120 | 165 | 165 |
| R ² | 0.257 | 0.260 | 0.589 | 0.618 | 0.435 | 0.442 |
| Regional quantity | 11 | 11 | 8 | 8 | 11 | 11 |
| Control year | YES | YES | YES | YES | YES | YES |
| Control area | YES | YES | YES | YES | YES | YES |

technological innovation as understood by most studies is not comprehensive, so the study uses empirical analysis to further explore the influence mechanism of environmental regulation on green technological innovation.

From the baseline regression test, it can be seen that the weak motivation of enterprises to innovate themselves and improve their production processes, as well as their weak ability to cooperate with regulation and reduce production pollution emissions, are the main reasons for their lack of

green innovation capacity. An extended analysis of the nonlinear effects shows that environmental regulations have a nonlinear impact on the efficiency of regional green technology innovation. Specifically, cost-input environmental regulations have a positive U-shaped effect on the efficiency of regional green technology innovation, while government-subsidized environmental regulations have an inverted U-shaped effect on the efficiency of regional green technology innovation. The results of the nonlinear impact analysis

TABLE 8: Estimated results of intermediary mechanism test.

| Variables | Cost-input environmental regulation | | | Government-subsidized environmental regulation | | |
|-------------------|-------------------------------------|------------------------|------------------------|--|------------------------|-----------------------|
| | (1) TE | (2) finadd_sta | (3) TE | (4) TE | (5) finadd_sta | (6) TE |
| lner | -0.023 ** (-2.309) | -0.001 ** (-2.067) | -0.023 ** (-2.309) | | | |
| environ | | | | 1.177 *** (2.785) | 0.632 *** (2.885) | 1.160 *** (2.714) |
| finadd_sta | | | 0.063 ** (2.678) | | | 0.027 ** (2.284) |
| rdgdp | 0.075 *** (2.899) | 0.132 *** (9.692) | 0.084 *** (-2.907) | 0.087 *** (3.328) | 0.126 *** (9.225) | 0.091 *** (3.145) |
| tel | 0.727 *** (5.067) | 0.528 *** (7.052) | 0.693 *** (4.563) | 0.700 *** (4.869) | 0.502 *** (6.746) | 0.686 *** (4.527) |
| ins | -0.071 ** (-2.450) | -0.124 *** (-8.139) | -0.063 ** (-2.021) | -0.023 ** (-2.667) | -0.108 *** (-6.893) | -0.020 ** (-2.635) |
| open | -0.092 * (-1.934) | -0.219 *** (-8.834) | -0.078 (-1.503) | -0.105 ** (-2.251) | -0.217 *** (-8.949) | -0.099 * (-1.944) |
| urban | -0.593 *** (-4.247) | 0.570 *** (7.820) | -0.629 *** (-4.205) | -0.110 (-0.598) | 0.764 *** (8.006) | -0.130 (-0.660) |
| Constant | 1.222 *** (11.966) | -0.184 *** (-3.456) | 1.234 *** (11.903) | 0.806 *** (6.887) | -0.317 *** (-5.235) | 0.815 *** (6.733) |
| Observed value | 450 | 450 | 450 | 450 | 450 | 450 |
| R ² | 0.529 | 0.802 | 0.541 | 0.551 | 0.806 | 0.592 |
| Regional quantity | 30 | 30 | 30 | 30 | 30 | 30 |
| Control year | YES | YES | YES | YES | YES | YES |
| Control area | YES | YES | YES | YES | YES | YES |

TABLE 9: Test results of robustness and endogeneity.

| Variables | (1) TE | (2) TE | (3) TE | (4) TE |
|-------------------|---------------------|--------------------|---------------------|---------------------|
| lner | -0.033 *** (-2.725) | | -0.023 *** (-0.440) | |
| environ | | 1.136 *** (2.589) | | 1.587 ** (2.501) |
| rdgdp | 0.062 ** (2.354) | 0.078 *** (2.891) | 0.070 ** (1.964) | 0.085 (0.699) |
| tel | 0.679 *** (4.770) | 0.663 *** (4.625) | 0.889 *** (2.923) | 0.662 * (1.852) |
| ins | -0.078 *** (-2.634) | -0.029 (-0.940) | 1.148 ** (2.151) | 1.053 ** (2.106) |
| open | -0.082 * (-1.701) | -0.103 ** (-2.163) | 0.250 ** (2.161) | 0.271 ** (2.245) |
| urban | -0.644 *** (-4.496) | -0.154 (-0.815) | -1.016 * (-1.652) | -0.292 *** (-7.010) |
| L.TE | | | -0.200 *** (-4.698) | -0.358 *** (-5.289) |
| Constant | 1.266 *** (11.90) | 0.823 *** (6.934) | — | — |
| Observed value | 405 | 405 | 390 | 390 |
| R ² | 0.154 | 0.152 | — | — |
| Regional quantity | 30 | 30 | 30 | 30 |
| Control year | YES | YES | YES | YES |
| Control area | YES | YES | YES | YES |

corroborate the regression results of the benchmark model and meet the relevant findings of previous studies [23].

From a heterogeneity perspective, cost-input-based environmental regulation has a significant inhibitory effect on the eastern and central regions, and government-subsidized environmental regulation, an improvement in the central and western regions, while the inverted U-shaped effect of regional green innovation efficiency does not change as a result of subsampling. The test for the mediating mechanism found that improvements in regional financial resource allocation significantly contributed to the efficiency of regional green technology innovation. The cost-input type of environmental regulation has a

dampening effect on local financial resource allocation, while government-subsidized environmental regulation, on the contrary, improves local financial resource allocation, in line with the results of previous studies [24].

5. Conclusions and Policy Implications

This paper uses panel data from 30 Chinese provinces (cities and autonomous regions) from 2005 to 2019 to conduct an empirical analysis, and uses a mediating effects model to discuss the relationship between environmental regulation, financial resource allocation, and green technology innovation efficiency using financial resource allocation as a

mediating variable. The empirical results show that there is a significant correlation between the intensity of environmental regulation and green technology innovation efficiency. As the intensity of environmental regulation increases, the production cost of market enterprises increases, and the green technology innovation efficiency tends to decrease and then increase.

In the pursuit of economic growth, China has come to realize that administrative measures such as environmental regulation can reduce the “negative externalities” of environmental pollution. In order to better coordinate the relationship between environmental regulation and green technological innovation, this paper proposes the following recommendations: firstly, we should give full play to the role of environmental regulation; strengthen the awareness of ecological protection; effectively improve the scientific concept of development; actively abandon high energy consumption, high pollution, and low value-added projects; continue technological innovation; and accelerate the transformation to strategic emerging industries and tertiary industries. Secondly, we should focus on financial resource allocation reform, actively implement and improve financial policies related to green development, promote green technology innovation, make financial resource allocation better match with environmental regulations, and further match a series of related green production and operation activities of enterprises. Finally, we should continue to promote the development of a coordinated regional economy and an inclusive economy; improve the efficiency of regional green technology innovation; strive to create a green, low-carbon and circular economic system; and scientifically handle the relationship between environmental protection and economic development.

Data Availability

No data were used to support the findings of the study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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