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Impact of Heterogeneous Environmental Regulation on Ecological Industrialisation in the Upper Reaches of the Yangtze River in the Context of "Internet + Big Data"

Abstract: - The solution to the ecological and protection conundrum in the upper reaches of the Yangtze River lies in ecological industrialization, which is predicated on ecological preservation and has the capacity to convert local ecological advantages into economic advantages. Environmental regulations are essential to the ecological industrialization process since they help to solidify the base of resource endowment and guarantee the industrialization process's steady progression. There may be a relationship between environmental laws and eco-industrialization, according to the research. With the rapid development of new-generation information technology such as the Internet, big data, cloud computing and the Internet of Things, it is of great significance to strengthen the Internet and big data to empower eco-industrialisation development. Using a panel regression model, the influence and moderating function of environmental regulations on eco-industrialization were examined. The findings demonstrate that environmental rules with a focus on public engagement and command-and-control encourage area eco-industrialization. Nonetheless, the degree of regional eco-industrialization was lowered by the market incentive form of environmental control. It was also determined whether environmental laws had a moderating effect on eco-industrialization. The findings of the mediating impact demonstrate how, through the mediating function of upgrading the industrial structure, all three environmental regulations influence the evolution of eco-industrialization. In conclusion, this study makes the case that environmental legislation has a significant impact on eco-industrialization. Simultaneously, consideration needs to be given to how various forms of environmental control affect eco-industrialization. To this purpose, upgrading the eco-industrialization level of the upper reaches of the Yangtze River requires a reasonable regulation of the strength of environmental regulations. This justifies accelerating the industrial structure's upgrade.

Keywords: Internet; Big data; Environmental Regulations; Ecological Industrialization; Realizing the Value of ecological Products; Ecological Civilization Construction.

I. INTRODUCTION

A viable strategy for advancing China's high-quality growth and ecological civilization building is eco-industrialization. It is an objective need in the next phase of China's ecological civilisation for the ecological environment to keep getting better. They are becoming increasingly intolerant of environmental degradation, abuse of ecological resources, and other environmental destruction phenomena. At present, people are paying more attention to resource resource conservation, more attention to environmental friendliness and more attention to ecological protection. The next stage of superior growth must be reached by promoting the development of new economic growth dynamics that place an emphasis on environmental preservation in addition to economic growth. The 2018 National Conference on Ecological Environmental Protection put out the idea of building an ecological economic system, with the industrialization of ecology and the ecologization of industry serving as its cornerstones. In 2021, the Opinions on Establishing a Sound Mechanism for Realising the Value of Ecological Products was released, and the need to promote eco-industrialisation was again proposed. The conversion of a region's advantages in ecological resources into benefits for the growth of its economy is known as eco-industrialization. Eco-industrialization is currently a viable route toward the development of an ecological civilization.

At the same time, with the rapid development of the digital economy in China, information technology has played a significant role in stimulating independent innovation and promoting market connectivity, and has injected new momentum into economic growth. Eco-industrialisation is an important pillar in the construction of

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an eco-economic system, and it is of great practical significance to strengthen the empowerment of information technology to promote the development of eco-industrialisation. Research has shown that computer information technology has a powerful boost in the process of promoting rural eco-industrialisation or rural construction, mainly in the following aspects: firstly, multi-channel publicity and promotion of rural characteristics; secondly, expanding the value-added space of the rural eco-industrial industry chain; and thirdly, setting up a comprehensive platform for rural eco-industrialisation information[1]; Use of big data technology to build a database of natural resources and realise the scientific arrangement of relevant resources[2]. In 2021, the No.1 Document of the Central Government proposed to "implement the digital countryside construction and development project" and "promote the green development of agriculture"; In 2022, the "No.1 Document" of the central government will further emphasise "vigorously promoting the construction of digital villages" and "promoting the green development of agriculture and rural areas". It can be seen that under the new situation, promoting the integration of information technology and eco-industrialisation has become a necessary way to promote rural revitalisation and achieve high-quality economic development.

The upper reaches of the Yangtze River (URYR) serve as a key maneuvering space for the "Belt and Road" and other national plans, in addition to serving as a pioneer and demonstration location for the enlargement of the western portion of China and the Yangtze River Economic Belt. The population of URYR expanded quickly in the middle to late 20th century, as did the economy and the urbanization process. However, this was accompanied by problems such as resource abuse and waste, ecosystem degradation and water loss. URYR has undertaken a number of preservation and restoration projects, like the natural forest conservation project, to manage the eco environment in an effort to ameliorate the situation. There is no denying the success of this set of natural environmental protection and management initiatives. The biological environment of URYR has improved overall as a result of these management efforts, but there are still significant obstacles to overcome, including dwindling biodiversity and fragile ecosystems. As a result, URYR continues to have to balance its goals of ecological preservation and excellent financial growth. Encouraging eco-industrialization in URYR is very important. An essential mechanism for balancing prosperity and ecological preservation is environmental control. Therefore, it is necessary to investigate whether rules governing the environment have a good or detrimental effect on eco-industrialization. Environmental restrictions have the effect of driving out businesses' innovation and production at the micro level by raising the total expense of environmental management for them. Under certain conditions, this crowding-out effect will prompt enterprises to produce cleaner products, such as eco-products. The production and value realisation of eco-products is essentially a process of eco-industrialisation. On one present, meso-level green laws will compel polluting businesses to close. The laws governing the environment, on the other present, are supposed to promote the entry of clean sectors like the eco-industry. Eco-industry is the inevitable requirement of eco-industrialisation. Therefore, in this sense, environmental regulation may promote the development of eco-industrialisation.

II. Literature Review

From an industrial perspective, eco-industrialisation is the transformation of regional ecological resource advantages into regional industrial development advantages. The transformation of this advantage is manifested in the formation of eco-industry. Although there is now a dearth of research on environmental regulation and eco-industry, there is a wealth of studies on governance of the environment, the natural setting, and business growth in the literature that is already available.

A. Environmental Regulations' Effects on the Natural Environment

There are two opposing viewpoints in the study of ecological quality and conservation. To begin with, the ecosystem's quality has increased as a result of environmental restrictions. Environmental rules have been proven to minimize emit toxins in the paper industry in Quebec, Canada, and the US, according to research by Laplante and Rilstone[3]. Environmental legislation is particularly effective in controlling pollution, according to research by Langpap et al. that looked at the effects of regulatory policies on the ecosystem from the standpoint of informal ecological control[4]. Cadman et al. demonstrated through their study that environmental regulation contributes to marine conservation in Canada[5]. By dividing regulatory measures for the environment into two categories—formal and informal—Matthew et al. investigated the relationship between environmental regulation and air pollution and discovered the two can significantly enhance air quality[6]. Environmental control has a major impact on haze reduction, according to research by Li et al. on the subject of haze[7]. Slavíková et al. testify that legislation governing the environment in Germany and the Czech Republic fosters biodiversity governance, using informal environmental regulation as an example[8]. Second, environmental regulations have failed to improve the quality of the ecosystem. Using Indian cluster industries as a case study, Goldar and Banerjee investigated the effect of environmental legislation on water quality and discovered that it had no discernible positive effect[9]. Research on the relationship between environmental regulation and company control of emissions was conducted by Blackman and Kildegaard, who discovered that there is little correlation between the two[10]. When the aforementioned research are combined, it becomes clear that differing opinions exist regarding how environmental regulations affect the overall condition of our natural surroundings. This issue has to be further investigated.

B. Environmental Aspects Restrictions' Effects on Growth in Industries

Extensive and affluent academic study has been carried out about the influence of ecological control on the growth of industry, leading to the emergence of three distinct perspectives.

On the one hand, there is the viewpoint that environmental legislation is harmful to different industries. The "compliance cost hypothesis" is the basis for this viewpoint. According to this hypothesis, the enforcement of regulations pertaining to the environment will invariably result in additional environmental governance costs for businesses, which will ultimately cause a rise in the total costs of businesses. This view is supported by the fact that Gollp and Roberts, Walley and Whitehead, and others have pointed out that this will happen. In the environment of short-term technology and demand, which is difficult to modify rapidly, an increase in total cost will result in a reduction in the profits of businesses, which is not beneficial to the development of the entire sector[11-12].The findings of a study conducted by Jorgenson and Wilcoxen, which revealed that the implementation of environmental control results in a reduction in the level of gross national product[13], provided evidence that this viewpoint is correct. Not only that, but Barbera and McConnell, who used the productivity of industrial firms in the United States from 1960 to 1980 as the subject of their research, discovered that environmental regulation has a negative impact on the productivity of businesses[14].

Some people believe that environmental control is beneficial to the growth of industries. This is the second viewpoint. The Porter's hypothesis is the primary source of inspiration for this viewpoint[15]. Over the course of time, businesses will improve their technological capabilities, as well as select and deploy technologies that are more effective in terms of output and emission reduction, in response to the introduction of environmental rules. The introduction of new technologies results in an improvement in productivity, which in turn is beneficial to the overall growth of the sector.

According to the third point of view, the good impact that regulatory compliance has on the development of industry is not an absolute or unqualified one; rather, it is contingent upon other factors, such as the features of the industry and the variations in market players. In the case of environmental regulation, for instance, a greater degree of regulation works as a barrier to market entry for other companies, which enables those companies to take advantage of larger monopoly profits. The fact that businesses that do not comply with environmental regulatory norms are severely barred from entering the market, on the other hand, has a detrimental effect on the growth of the industrial landscape.

C. Research Review

In conclusion, the majority of the studies that have been conducted thus far concentrate on the effects of environmental laws on the development of industrial and ecological environments. On the other hand, there are a limited number of research that investigate the effects of environmental regulation from the point of view of ecological and industrial integration. In light of this, the purpose of this paper is to suggest an investigation into the influence that environmental regulation has on ecological industrialization. This investigation would be of considerable theoretical relevance in terms of supplementing the research that is being done in the field of environmental regulation.

III. Methodologies of Research and the Establishment of Models

A. Methods of Study and Sources of Information

1) Research Methods

(1) Entropy weighting method

Entropy weighting is a method for assessing the uncertainty of discrete random variables[16]. Within the context of multiple-purpose the making of decisions and appraisal, its entropy has the potential to enhance the precision of decision-making information by increasing the quantity of information. To put it another way, the orderliness of the information is high when the weight of an indication is high, and the information entropy is low when the weight is low. The following is a list of the main stages involved in the entropy weighing approach:

① Create the first decision grid

Assuming the sample set consists of m samples and n variables, the jth variable in the ith sample is evaluated as r_{ij}, at which time all the variables combine to produce the decision matrix that follows:

$$R=\left(r_{ij}\right)=\begin{pmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{pmatrix} \tag{1}$$

② Standardize the initial indicator level matrix data. Standardize the initial indicator matrix using the range method based on the category of indicators.

The normalization formula for the raw data of positive indicators is as follows:

$$r_{ij}'=\frac{r_{ij}-\min\left(r_{ij}\right)}{\max\left(r_{ij}\right)-\min\left(r_{ij}\right)} \tag{2}$$

The normalization formula for the raw data of negative indicators is as follows:

$$r_{ij}'=\frac{\max\left(r_{ij}\right)-r_{ij}}{\max\left(r_{ij}\right)-\min\left(r_{ij}\right)} \tag{3}$$

Due to the possibility of assessed values of 0 during the standardisation process, the standardised values were shifted by a small amount for the convenience of subsequent calculations:

$$r_{ij}=r_{ij}'+10^{3} \tag{4}$$

③ Determine indicator weights

Determine the standardized indicator j's entropy:

$$e_j=-k\sum_{i=1}^{m} r_{ij}\ln r_{ij},\ j=1,2,\cdots,n \tag{5}$$

Among them, when $k=1/\ln m$, $0\le e_j\le 1$ and $r_{ij}=0$, $r_{ij}\ln r_{ij}=0$.

If E represents the total entropy of the indicator, then:

$$E=\sum_{j=1}^{n} e_j=\frac{1}{\ln n}\sum_{j=1}^{n}\sum_{i=1}^{m} r_{ij}\ln r_{ij} \tag{6}$$

The coefficient of variation dj of the assessed value data for the jth indicator can be expressed as

$$d_j=1-e_j,\ j=1,2,\cdots,n \tag{7}$$

For the jth indicator, the smaller e_j, the greater the difference d_j in r_{ij}, and the greater the impact on evaluating r_{ij} in the sample; If every r_{ij} is the same, $e_j=e_{\max}=1$, $d_j=0$. According to this, the jth indicator is meaningless in the overall assessment; the difference d_j of r_{ij} is less the larger the e_j.

The weight factor of the jth indicator is:

$$\omega_j=\frac{d_j}{\sum_{j=1}^{n} d_j}=\frac{1-e_j}{\sum_{j=1}^{n}\left(1-e_j\right)}=\frac{\left(1-e_j\right)}{n-E} \tag{8}$$

(2) TOPSIS evaluation model

The TOPSIS approach first determines the distances between them between every sample and the ideal solutions, positive as well as detrimental, before ranking the results and choosing the best option. A sample is considered superior if it is situated closer to the positive ideal solution and further away from the negative ideal solution[17].The TOPSIS method's precise calculation stages are basically as follows:

① Indicator weight matrix

Calculate the weighted matrix of indicator values based on the standardized grid for making decisions $R=\left(r_{ij}\right)_{m\times n}$ and the entropy weight ω_j of each indicator obtained above:

$$v=\begin{pmatrix}\omega_1 r_{11} & \cdots & \omega_n r_{1n}\\ \vdots & \ddots & \vdots\\ \omega_1 r_{m1} & \cdots & \omega_n r_{mn}\end{pmatrix}=\begin{pmatrix}v_{11} & \cdots & v_{1n}\\ \vdots & \ddots & \vdots\\ v_{m1} & \cdots & v_{mn}\end{pmatrix} \tag{9}$$

② Identify optimal solutions that are beneficial and detrimental

$$V^+=\left\{v_1^+,v_2^+,\cdots,v_n^+\right\}=\left\{\left(\max v_{ij}\,|\,j\in J_1\right),\left(\max v_{ij}\,|\,j\in J_2\right)\right\} \tag{10}$$

$$V^-=\left\{v_1^-,v_2^-,\cdots,v_n^-\right\}=\left\{\left(\min v_{ij}\,|\,j\in J_1\right),\left(\min v_{ij}\,|\,j\in J_2\right)\right\} \tag{11}$$

Among them, V^+ denotes a favorable optimal solution, while V^- denotes an unfavorable optimal solution, $i=1,2,\cdots,m$.

③ Determine the Euclidean distance

The formula for computing the distance of both negative and positive optimal solutions is:

$$L_i^+=\sqrt{\sum_{i=1}^{m}\left(v_{ij}-v_j^+\right)^2},i=1,2,\cdots,m \tag{12}$$

$$L_i^-=\sqrt{\sum_{i=1}^{m}\left(v_{ij}-v_j^-\right)^2},i=1,2,\cdots,m \tag{13}$$

④ Calculate TOPSIS evaluation value

Sort the values according to their size to form an order table, which is calculated using the formula:

$$Y_i=L_i^-\Big/\left(L_i^++L_i^-\right) \tag{14}$$

2) Data Sources: This article utilizes the pertinent data of URYR spanning from 2005 to 2022. The primary sources of data consist of the China Area Economic Statistics Yearbook, China City Statistics Yearbook, provincial statistical yearbooks, and the Wind Database. For partially missing data, we use interpolation method for fitting processing. Due to the fact that the control variables in the model involve absolute number indicators, while the chosen dependent variable in the study is a relative value indicator, in order to control for estimation bias and heteroscedasticity issues, we logarithmized the relevant variables. From the statistical characteristics of the variables (Table 1), it can be seen that the indicators of rural population share, population density, and GDP per capita have large standard deviations, revealing that these indicators vary considerably from one region to another.

Table 1: Descriptive Statistics of Variables

Variable	Sample size	Average value	Standard deviation	Minimum value	Maximum value
ECOI	846	0.102	0.158	0.003	0.683
EER	846	0.069	0.730	-1.399	2.560
MER	846	0.073	0.114	0.002	0.778
AER	846	0.316	0.135	0.069	0.807
RI	846	0.260	0.134	0.131	0.752
PR	846	51.451	6.036	40.790	61.703
PD	846	289.085	293.270	1.390	1325.000
EC	846	31206.070	105105.200	1032.040	1300000.000
LF	846	13.900	1.244	7.990	17.931
AIS	846	7.326	1.312	3.807	11.138

B. Variable Description

1) Dependent Variable: At present, research on the measurement of ecological industrialization has become increasingly abundant. Starting from the connotation of eco-industrialisation, this paper overcomes the limitation of the lack of consensus on the valorisation and marketisation of ecological products, and constructs an evaluation index system of eco-industrialisation by combining with the actual situation of the upper Yangtze River region. Eco-industrialisation is essentially the capitalisation and marketisation of rich ecological resources, the organic combination of ecological protection and industrial development, and the industrialisation of ecological resources as a means to achieve win-win economic and ecological benefits and to ensure the integrity and sustainable use of ecological resources. According to the ultimate benefits of ecological industrialization, which include economic and ecological benefits, ecological industrialization is divided into two subsystems: economic and ecological benefits. Further, indicator systems are constructed for each subsystem, and comprehensive indicator measurement is carried out using the entropy weight TOPSIS method.

The economic benefits of ecological industrialization are mainly reflected in the economic benefits obtained by the main body of ecological industrialization in the process of ecological industrialization. Specifically, the main body of ecological industrialization, namely ecological protection, ecological restoration, and ecological reconstruction, provides ecological products or services to the market through the assetization, valuation, and capitalization of ecological resources, and can obtain economic benefits from the transactions of ecological products or services in the ecological economy market[18]. The forms of ecological industrialization include basic planting and animal husbandry, traditional processing industry, and emerging tourism industry, providing new paths to meet human needs and promote economic development[19]. Therefore, ecological industrialization covers three major categories: agriculture, industry, and service industry. Peng et al. also pointed out that ecological industries mainly include three categories: ecological agriculture, ecological industry, and ecological service industry[20]. Eco-agriculture is subdivided into agriculture, forestry, animal husbandry and fisheries, while eco-services are mainly represented by eco-tourism. Based on this, mainly referring to the research of Ren and Tang[21], Chen[22], and Bao et al.[23], ecological agriculture industrialization, ecological forestry industrialization, ecological animal husbandry industrialization, ecological fishery industrialization, ecological industry industrialization, and ecological tourism industrialization are selected to reflect. Specifically: (1) The level of eco-agricultural industrialisation is reflected in a combination of gross agricultural output, food production per unit area and gross agricultural output per hectare of arable land. (2) Eco-forestry industrialisation is expressed in terms of total forestry output value. (3) Eco-animal husbandry industrialisation is expressed in terms of gross value of livestock production. (4) Eco-fishery industrialisation is expressed in terms of total fishery output value. (5) Eco-industrial industrialisation is expressed in terms of gross industrial output value. (6) Eco-tourism industrialisation is expressed in terms of total tourism income and annual growth rate of tourism income.

For ecological benefits, the ecological industry has two significant characteristics: firstly, the negative environmental impact in the initial stage does not exceed the ecological carrying capacity; Secondly, during the development process, the negative environmental impact gradually weakens and tends to zero. And this change can be measured by the decline rate of indicators such as resource consumption, pollution amount, and pollution concentration per unit product[24]. Ecological industrialization is the provision of ecological services through socialized large-scale production and market-oriented management, and is the path to the formation of ecological industries. Therefore, referring to the research of Wang and others, the resource consumption level and resource recycling level per unit of output are selected to reflect[25]. The three indicators of energy, electricity and water usage as a percentage of GDP are used to comprehensively reflect the degree of resource consumption. To thoroughly assess the level of resource recycling, three metrics are used: the rate of thorough utilization of industrial solid waste, the rate of treatment of urban sewage, and the percentage of safe treatment of household garbage. Table 2 displays the eco-industrialization assessment indicator framework.

Table 2: Ecological Industrialization Evaluation Index System

System	Subsystem	Indicator categories	Specific indicators
ecological industrialization level	economic benefits	Industrialization of ecological agriculture	Gross worth of farming goods
			Overall amount of crop production per hectare of land used for farming
			Grain yield per unit area
		Industrialization of Ecological Forestry	Total output value of forestry
		Industrialization of ecological animal husbandry	Value of raising animals as a whole
		Industrialization of Ecological Fisheries	Total fishery output value
		Industrialization of ecological industry	Total industrial output value
		Industrialization of ecotourism	Total tourism revenue
			Annual growth rate of tourism revenue
	ecological benefit	The level of resource consumption per unit output	gdp energy intensity
			Energy intensity of GDP
			Water usage as a percentage of GDP
		Resource recycling level	Percentage of full usage of industry solid waste
			Rate of treating waste in cities
			Rate of benign disposal of domestic garbage

2) Explanatory Variables: The measurement methods of environmental regulation are constrained by the research objectives, research objects, implementation conditions and so on. Therefore, when choosing environmental regulation indicators and measurement techniques, this paper takes into account the principles of feasibility, reliability, and consistency of indicators. It then chooses indicators for command-and-control, market-incentivised, and public-participation regulations concerning the environment, respectively, as follows:

The present study chooses the following indicators for assessing the strength of command-and-control regulation regarding the environment based on the evaluation indicators of Bo et al.[26], He et al.[27], Guo et al.[28], and Wu et al.[29]. These indicators include the number of environmental administrative penalties per capita, the number of rules and regulations imposed by the local authority, the number of conservation initiatives carried out in the current year, the ratio of the environmental governance investment in the current year in the GDP, and the number of individuals in the region's environmental preservation groups in the current year.

For market incentivised environmental regulation (MER), the studies of Wu and Hui[30], Shen et al[31] and Guo[28] are mainly referred to. Three indicators are selected to reflect the logarithm of the revenue from sewage charges, a dummy variable for the time when the pilot cities started to establish and implement the trading platform for sewage rights, and the proportion of municipal finance spending on general budget items to spending on safeguarding the environment.

Regarding public participation in environmental regulation, this essay primarily utilizes the studies of Bo et al[26] and Wu and You[32]. On this basis, considering data availability and reliability, the overall number of NPCs and the quantity of environment-related letters suggestions and CPPCC proposals in the same year, the number of letters and visits that have been closed, and the number of scientific research organisations are selected to reflect the extent of regional environmental control through citizen involvement. Table 3 displays the environmental regulation's evaluation index system.

Table 3: Environmental Regulation Evaluation Index System

Indicator categories	Specific indicators
Command controlled environmental regulation intensity	Number of environmental administrative penalty cases in the area per person
	The quantity of laws and rules issued by local governments
	Number of projects that have been approved for environmental safety this year
	The amount of money spent on environmental management compared to GDP
	Employees of regional environmental institutions
The severity of environmental regulations based on market incentives	Income from pollution discharge fees
	Virtual variable of the time when pilot cities begin to establish and implement emission trading platforms
	The ratio of local general budget expenditures to fiscal expenditures for environmental protection
The level of public engagement in environmental control	Number of environmental letters
	The total amount of recommendations made by the Chinese People's Political Consultative Conference and the National People's Congress in that particular year
	The quantity of completed petitions
	The quantity of scientific research institutions

3) Intermediary factors: Upgrading industrial structure is the intermediary factor used in this article. This work employs the industrial structure level index to characterize the improvement of industrial structures based on research by Zhang et al.[33]. The following is the precise calculation for improving the manufacturing structure:

$$AIS_{it} = \sum_{n=1}^{3} y_{\text{int}} \times n, n = 1, 2, 3 \tag{15}$$

In this equation, y_{int} denotes the percentage of the nth industry's industrial added value of region i in period t to GDP. If the value of AIS_{it} is higher, it indicates a better industrial structure.

4) Regulating Factors: Usually, the omission of explanatory variables will cause bias in the regression results, which in turn affects the objective estimation of policy effects in this paper. This work is based on research by Feng et al.[34] and introduces control variables related to the level of eco-industrialisation in the regression. Table 4 displays the particular control variables.

Table 4: Control Variable

Indicator categories	Specific indicators	Symbol
Rural informatization	Rural Internet penetration rate	RI
Rural population proportion	Rural population proportion	PR
Population size	Population density	PD
Regional economic development level	Per capita GDP	EC
Local fiscal expenditure level	Expenditure within the general budget of local finance	LF

C. Research Model Building

1) Construction of Standard Regression Model: In order to empirically test environmental regulations' effects on eco-industrialization, according to the variety of environmental regulations, this paper constructs benchmark regression models as follows, respectively:

$$ECOI_{it} = C + \alpha_1 EER_{it} + \alpha_2 RI_{it} + \alpha_3 PR_{it} + \alpha_4 PD_{it} + \alpha_5 EC_{it} + \alpha_6 LF_{it} + \varepsilon_{it} \quad (16)$$

$$ECOI_{it} = C + \alpha_1 MER_{it} + \alpha_2 RI_{it} + \alpha_3 PR_{it} + \alpha_4 PD_{it} + \alpha_5 EC_{it} + \alpha_6 LF_{it} + \varepsilon_{it} \quad (17)$$

$$ECOI_{it} = C + \alpha_1 AER_{it} + \alpha_2 RI_{it} + \alpha_3 PR_{it} + \alpha_4 PD_{it} + \alpha_5 EC_{it} + \alpha_6 LF_{it} + \varepsilon_{it} \quad (18)$$

In equations (5.2), (5.3) and (5.4), C is the intercept term, EER, MER and AER stand for environmental rules based on market incentives, public engagement, and command and control, respectively, ECOI is eco-industrialisation, RI, PR, PD, EC and LF are factors that are under control, α_1 is the coefficient of the corresponding environmental regulation, α_1-α_6 are the coefficients of the control variables, respectively, and ε is the residual term.

2) Construction of mediation effect model: On the basis of the benchmark regression analysis of the influence of command-and-control environmental regulation on eco-industrialization, This research delves deeper into the intermediary mechanism of manufacturing structure improvement. To this end, the mediation model is constructed as follows:

$$ECOI_{it} = C + \alpha_1 EER_{it} + \alpha_2 AIS_{it} + \alpha_3 RI_{it} + \alpha_4 PR_{it} + \alpha_5 PD_{it} + \alpha_6 EC_{it} + \alpha_7 LF_{it} + \varepsilon_{it} \quad (19)$$

$$AIS_{it} = C + \alpha_1 EER_{it} + \alpha_2 RI_{it} + \alpha_3 PR_{it} + \alpha 4 PD_{it} + \alpha_5 EC_{it} + \alpha_6 LF_{it} + \varepsilon_{it} \quad (20)$$

This research expands on the benchmark regression analysis of the influence of market-driven environmental regulations on the development of eco-industrialization. It specifically investigates the mediating mechanism of industrial structure upgrading. To this end, the mediation model is constructed as follows:

$$ECOI_{it} = C + \alpha_1 MER_{it} + \alpha_2 AIS_{it} + \alpha_3 RI_{it} + \alpha_4 PR_{it} + \alpha_5 PD_{it} + \alpha_6 EC_{it} + \alpha_7 LF_{it} + \varepsilon_{it} \quad (21)$$

$$AIS_{it} = C + \alpha_1 MER_{it} + \alpha_2 RI_{it} + \alpha_3 PR_{it} + \alpha 4 PD_{it} + \alpha_5 EC_{it} + \alpha_6 LF_{it} + \varepsilon_{it} \quad (22)$$

This study expands upon the benchmark regression analysis that examines the influence of public participatory environmental regulation on eco-industrialization. It delves deeper into the mediating mechanism of this relationship, specifically focusing on the upgrading of industrial structure. To this end, the mediation model is constructed as follows:

$$ECOI_{it} = C + \alpha_1 AER_{it} + \alpha_2 AIS_{it} + \alpha_3 RI_{it} + \alpha_4 PR_{it} + \alpha_5 PD_{it} + \alpha_6 EC_{it} + \alpha_7 LF_{it} + \varepsilon_{it} \quad (23)$$

$$AIS_{it} = C + \alpha_1 AER_{it} + \alpha_2 RI_{it} + \alpha_3 PR_{it} + \alpha 4 PD_{it} + \alpha_5 EC_{it} + \alpha_6 LF_{it} + \varepsilon_{it} \quad (24)$$

The above formula symbols have the same meaning as above.

IV. Result Analysis

A. Correlation Analysis of Variables

The Pearson correlation analysis was conducted to examine the association between the dependent, independent, and control variables. The results, presented in Table 5, indicate a statistically significant correlation among the variables. Moreover, the magnitude of the correlation coefficient between the independent variables does not exceed 0.8, suggesting the absence of multicollinearity between the independent variables and the dependent variables. Furthermore, there is a statistically significant correlation between command-and-control environmental regulation and eco-industrialisation at the 1% level. Similarly, market-incentive environmental regulation and eco-industrialisation also show a significant correlation at the 1% level. Additionally, public-participation environmental regulation and eco-industrialisation exhibit a significant correlation at the 1% level. A correlation exists between public participation in environmental control and eco-industrialization.

Table 5: The Correlation Test Results between Variables

Variable	ECOI	EER	MER	AER	RI	PR	PD	EC	LF
ECOI	1.000								
EER	0.179***	1.000							
MER	0.182***	0.292***	1.000						
AER	0.207***	0.611***	0.226***	1.000					
RI	0.034	0.318***	0.100***	0.349***	1.000				
PR	-0.036	0.012	-0.066*	0.031	0.069**	1.000			
PD	-0.006	-0.302***	-0.103***	0.065*	0.165***	0.004	1.000		
EC	0.132***	-0.029	0.525***	0.031	-0.073**	-0.083**	0.147***	1.000	
LF	0.057*	-0.014	-0.083**	0.066*	0.006	-0.014	0.327***	0.446***	1.000

Note: the symbols ***, **, and * correspond to statistical significance at the 1%, 5%, and 10% significance levels, respectively.

B. F Test and Hausman Test

According to the F-test results (Table 6), the F-test values for all models are not less than the checklist values, thus rejecting the null hypothesis that it is not appropriate to use a mixed regression model.

Table 6 F-test Results

F-test	(1)	(2)	(3)
Numerical value	6.51	6.10	5.56
Compare	F＞1.48	F＞1.48	F＞1.48
Conclusion	Refute the null hypothesis	Refute the null hypothesis	Refute the null hypothesis

Based on the F-test, the Hausmann test was further used to determine whether the model applies an individual effects model or a time effects model. The original assumption is that there is a correlation between the two, so it is advisable to choose a random effects model. According to the test results, at a 99% confidence level, the null hypothesis was rejected, indicating that there is no relationship between individual effects and explanatory variables. Therefore, a fixed effects model is recommended. The outcomes of the Hausmann test are displayed in Table 7.

Table 7: Hausman Test Results

Hausman test	(1)	(2)	(3)
Numerical value	78.36	93.68	62.98
Prob	0.0000	0.0000	0.0000
Conclusion	Refute the null hypothesis	Refute the null hypothesis	Refute the null hypothesis

C. Analysis of Benchmark Regression Results

The first column of Table 8 indicates that the regression coefficient for command-and-control environmental regulation on eco-industrialization is 0.027, and it is statistically significant at the 1% level. A 1% increase in the intensity of command-and-control environmental regulation leads to a 0.03% increase in eco-industrialisation. This could be attributed to the obligatory nature of command-and-control environmental regulation, which compels enterprises to implement pollution control measures and reduce pollution emissions once the policy is determined to be enforced. This ultimately aims to preserve ecological resources and foster eco-industrialization.

The data in Column (2) of Table 8 indicates that market incentive-based environmental legislation has a notably adverse impact on eco-industrialization. Each 1% rise in the intensity of market-driven environmental regulation leads to a corresponding fall of 0.21% in eco-industrialization. Market-based environmental regulation requires market regulation, resulting in a time delay. Therefore, when the market incentive-based environmental regulatory system began to implement, so that the binding effect on the polluting enterprises can not be immediately apparent, ecological resources and the environment is not immediately effective protection, inhibiting the development of eco-industrialisation. Simultaneously, in the immediate term, market incentive-based environmental regulation does not yield instant results, clean technology is not yet upgraded and improved, will also inhibit the development of eco-industrialisation.

Based on the findings in column (3) of Table 8, it can be observed that citizen participation environmental management has a favorable impact on eco-industrialisation. A 1% rise in the intensity of public participatory regulation regarding the environment leads to a corresponding 0.36% increase in the level of eco-industrialisation. As the economy and society progress, there is an increasing demand from individuals for a more favorable natural environment. Environmental regulations that involve public participation will compel businesses to implement environmental management practices, leading to the enhancement of the ecological environment and the preservation of resources. Consequently, this will drive the advancement of eco-industrialization.

Table 8: Benchmark Regression Results

Variable	(1)	(2)	(3)
	ECOI	ECOI	ECOI
EER	0.207***		
	(6.95)		
MER		-0.213***	
		(-3.40)	
AER			0.361***
			(3.71)
RI	0.754***	0.302**	0.201
	(3.23)	(2.00)	(1.34)
PR	-0.001	-0.000	-0.000
	(-0.67)	(-0.29)	(-0.03)
PD	0.000	0.000	0.000
	(0.57)	(1.00)	(0.89)
EC	0.000***	0.000***	0.000***
	(3.38)	(4.64)	(3.40)
LF	-0.048***	-0.039***	-0.020***
	(-7.20)	(-5.52)	(-4.63)
Constant	0.561***	0.557***	0.241***
	(5.25)	(5.83)	(3.45)
City	fixed	fixed	fixed
Year	fixed	fixed	fixed
Observations	846	846	846
R-squared	0.195	0.723	0.723
Number of id	47	47	47

Note: the symbols ***, **, and * correspond to statistical significance at the 1%, 5%, and 10% significance levels, respectively.

D. Endogeneity and Testing for Robustness

1) Evaluation for Endogeneity: In order to circumvent the endogeneity problem in regression analysis, a two-step system GMM model is used in this work. for endogeneity analysis. The GMM method with two steps mainly uses Arellano-Bond to test the random perturbation term. The AR(1) and AR(2) models indicate the presence of first-order and second-order serial correlation in the residual term following model differentiation, respectively. The results presented in Table 9 demonstrate the outcomes of the two-step systematic GMM model testing. Specifically, the p-values of the AR(1) test for all models are below 0.1, while the p-values of the AR(2) test exceed 0.1. This suggests that there is no presence of second-order autocorrelation in the residual terms. Furthermore, all of the p-values obtained from the Hansen test are greater than 0.1, suggesting that the selection of instrumental variables is both reasonable and effective. Furthermore, the coefficients of the lagged terms of eco-industrialisation at the first order were found to be statistically significant at a 1% level. This indicates that eco-industrialisation is an ongoing and uninterrupted process.

Table 9: Endogeneity Test Results

Variable	(1)	(2)	(3)
	ECOI	ECOI	ECOI
L.ECOI	0.857***	0.749***	0.905***
	(18.95)	(86.31)	(65.90)
EER	0.172***		
	(2.78)		
MER		-0.306***	
		(-12.92)	
AER			0.292***
			(5.33)
RI	-0.202	1.444***	0.021
	(-0.72)	(28.34)	(0.36)
PR	-0.000	-0.000	-0.002***
	(-0.00)	(-0.63)	(-6.23)
PD	0.000*	-0.000***	-0.000***
	(1.84)	(-3.15)	(-3.04)
EC	0.000	0.000***	-0.000*
	(0.47)	(8.53)	(-1.94)
LF	0.004	-0.086***	0.019***
	(0.40)	(-14.44)	(5.11)
Constant	-0.025	0.091**	0.158**
	(-0.14)	(2.03)	(2.13)
AR(1)	0.000	0.000	0.000

AR(2)	0.286	0.115	0.144
Hansen	0.167	0.205	0.816
Observations	799	799	799

Note: the symbols ***, **, and * correspond to statistical significance at the 1%, 5%, and 10% significance levels, respectively.

2) Robustness Testing: The robustness test is to confirm the accuracy and reliability of the benchmark regression results. In the robustness test, this work use the entropy weight approach. to recalculate the indicators of eco-industrialisation, and substitutes the new variables into the regression model for testing, and the findings are displayed in Table 10.

Table 10: Results of the Robustness Test

Variable	(1)	(2)	(3)
	ECOI	ECOI	ECOI
EER	0.206***		
	(6.94)		
MER		-0.213***	
		(-3.42)	
AER			0.364***
			(3.76)
RI	0.758***	0.310**	0.209
	(3.27)	(2.07)	(1.40)
PR	-0.001	-0.000	-0.000
	(-0.68)	(-0.30)	(-0.04)
RD	0.000	0.000	0.000
	(0.57)	(1.00)	(0.90)
EC	0.000***	0.000***	0.000***
	(3.40)	(4.68)	(3.43)
LF	-0.048***	-0.039***	-0.020***
	(-7.23)	(-5.56)	(-4.67)
Constant	0.560***	0.556***	0.239***
	(5.26)	(5.86)	(3.45)
Observations	846	846	846
R-squared	0.196	0.724	0.725
Number of id2	47	47	47

Note: the symbols ***, **, and * correspond to statistical significance at the 1%, 5%, and 10% significance levels, respectively.

E. Analysis of Mediation Effect Results

The results of the model test on the mediating influence of command-and-control environmental regulation on eco-industrialization are presented in Model (1) in Table 11. The regression analysis reveals a significantly positive coefficient for the impact of command-and-control environmental regulation on industrial structure upgrading. This suggests that command-and-control measures have a substantial beneficial influence on the upgrading of industrial structure. Furthermore, there is a strong positive correlation between the coefficient of industrial structure upgrading and eco-industrialization, suggesting that upgrading the industrial structure has a beneficial impact on promoting eco-industrialization. Thus, based on the findings regarding the mediation effect, it can be concluded that industrial structure upgrading acts as a mediator in the relationship between command-and-control environmental regulation and eco-industrialisation. Command-and-control environmental regulation impacts the process of eco-industrialization by influencing the upgrading of industrial structure.

The second model in Table 11 presents the outcomes of the model test examining the mediating impact of market incentive-based environmental regulation on eco-industrialization. The regression analysis shows a significant positive relationship between market incentive-based environmental regulation and industrial structure upgrading. This suggests that market incentive-based environmental policies have a strong beneficial impact on the upgrading of industrial structure. Furthermore, the influence coefficient of industrial structure upgrading on eco-industrialisation is strongly negative, suggesting that industrial structure upgrading has a detrimental effect on eco-industrialisation. Based on the results of the mediation effect, it can be concluded that the upgrading of industrial structure acts as a mediator in the relationship between command-and-control environmental regulation and eco-industrialisation. Market incentive-based environmental regulations have a favorable overall impact on eco-industrialization. This suggests that modernizing industrial structures helps to offset some of the negative effects of environmental regulations on eco-industrialization. Market incentive-based environmental regulation influences the process of eco-industrialization by facilitating the upgrading of industrial structure.

The results of the model test for the mediating influence of public participatory environmental control on eco-industrialisation are presented in Model (3) of Table 11. The regression analysis reveals a considerably positive coefficient for the relationship between public-participatory environmental regulation and industrial structure upgrading. This indicates that public-participatory environment has a notable beneficial impact on the upgrading of industrial structure. Furthermore, there is a strong positive correlation between the influence coefficient of industrial structure upgrading and eco-industrialisation. This suggests that industrial structure upgrading has a beneficial role in promoting eco-industrialisation. Thus, based on the findings of the mediation effect, the upgrading of industrial structure serves as a mediator in the relationship between public participatory environmental control and eco-industrialization. Public participation in environmental regulation influences the process of eco-industrialization by means of the mediating factor of upgrading industrial structure.

Table 11: Results of the Mediation Effect Test

Variable	Model(1)		Model(2)		Model(3)	
	AIS	ECOI	AIS	ECOI	AIS	ECOI
AIS		0.011**		0.017***		0.016***
		(1.99)		(4.97)		(4.56)
EER	0.533***	0.201***				
	(2.85)	(6.73)				
MER			1.526**	-0.240***		
			(2.41)	(-3.87)		
AER					2.514***	0.351***
					(3.16)	(3.65)
RI	4.919***	0.699***	1.415	0.277*	5.290***	0.172
	(3.36)	(2.98)	(0.93)	(1.87)	(3.97)	(1.16)
PR	0.004	-0.001	0.003	-0.000	0.004	-0.000
	(0.76)	(-0.73)	(0.71)	(-0.42)	(0.84)	(-0.14)
PD	0.000	0.000	0.000	0.000	0.000	0.000
	(0.42)	(0.54)	(0.63)	(0.90)	(0.29)	(0.80)
EC	0.000	0.000***	-0.000	0.000***	0.000	0.000***
	(0.51)	(3.35)	(-0.86)	(4.86)	(0.58)	(3.39)
LF	-0.088**	-0.047***	-0.044	-0.038***	-0.080**	-0.017***
	(-2.12)	(-7.04)	(-0.63)	(-5.49)	(-1.99)	(-3.96)
Constant	6.988***	0.482***	6.564***	0.443***	6.016***	0.112
	(10.44)	(4.24)	(6.80)	(4.57)	(11.99)	(1.50)
Observations	846	846	846	846	846	846
R-squared	0.092	0.199	0.186	0.731	0.094	0.731
Number of id2	47	47	47	47	47	47

Note: the symbols ***, **, and * correspond to statistical significance at the 1%, 5%, and 10% significance levels, respectively.

V. Summary and Recommendations

A. *Summary of Research Findings*

This paper begins by establishing an evaluation index system for environmental regulation and eco-industrialisation based on the existing literature. It then examines the impact of diverse environmental regulations on eco-industrialisation using panel data from the Upper Yangtze River Region spanning from 2005 to 2022. In addition, the mediation effect model is employed to examine the mediation effect of environmental legislation on eco-industrialization. This study derives the following conclusions from the outcomes of the preceding tests:

The impact of environmental legislation on eco-industrialisation varies due to heterogeneity. The regression analysis reveals that command-and-control, market-incentive, and public-participation environmental rules all exert a substantial influence on eco-industrialisation. Nevertheless, it is worth noting that both command-and-control and public-participation environmental rules contribute positively to the process of eco-industrialization, whereas market-incentive environmental regulations have an adverse impact on eco-industrialization. Hence, the impact of environmental regulation on eco-industrialization is substantial, albeit varying depending on the specific type of environmental control.

Furthermore, the implementation of command-and-control environmental regulation enhances the process of eco-industrialisation by encouraging the improvement of industrial structure. The test results demonstrate that command-and-control environmental regulation has a significant mediating effect on eco-industrialisation. Specifically, it is observed that command-and-control environmental regulation effectively enhances the upgrading of the industrial structure in URYR. Consequently, this upgrading of the industrial structure further stimulates the development of eco-industrialisation in URYR. Thus, it appears that the intermediate factor influencing the relationship between command-and-control environmental regulation and eco-industrialization is the upgrading of industrial structure.

In addition, market-based environmental regulation contributes to the advancement of eco-industrialisation through the encouragement of improvements in industrial structure. The test results indicate that market incentive-based environmental regulation has a significant impact on the promotion of industrial structure upgrading in URYR. Subsequently, the upgrading of industrial structure leads to a significant reduction in the level of eco-industrialisation in URYR. Furthermore, the influence of industrial structure mitigates the adverse impact of market-driven environmental regulations on eco-industrialization to some extent. Thus, the primary factor that mediates the relationship between market-driven environmental regulation and eco-industrialization is the upgrading of industrial structure.

Fourthly, the implementation of public participatory environmental control facilitates the improvement of industrial composition, so elevating the level of eco-industrialization. The findings demonstrate that public participatory environmental regulation plays a mediating role in the process of eco-industrialisation. Specifically, it is observed that public participatory environmental regulation has a significant positive impact on the enhancement of the industrial structure in URYR. Furthermore, the improvement of the industrial structure in turn has a significant positive effect on the level of eco-industrialisation in URYR. Thus, the mediating factor that influences the relationship between public participation in environmental regulation and eco-industrialization is the upgrading of the industrial structure.

B. Proposed Guidelines for Action

Initially, enhance the regulatory framework for environmental management and oversight. To enhance the development of eco-industrialization in URYR, it is necessary to continuously improve the supervisory system of environmental regulation and enhance the efficiency of implementing command-and-control environmental regulation. In order to effectively promote eco-industrialisation, it is important to develop a robust command-and-control environmental regulatory strategy that takes into account the intricate and varied nature of policy implementation issues and aims in URYR. Simultaneously, it is necessary to design a scientifically sound and rational command-and-control environmental regulating policy that takes into account the economic development, industrial structure, and human capital of URYR.

Secondly, it is important to guarantee that the market-driven environmental regulation is implemented at a fair level of intensity. The empirical test results of this research demonstrate that the market incentive-based environmental regulation in URYR hinders the process of eco-industrialisation. To promote eco-industrialization, it is important to develop market incentive-based environmental regulation in a way that keeps its intensity within a tolerable range. Simultaneously, it is imperative to proactively steer market enterprises towards implementing green technological innovation. This will effectively harness the "innovation compensation effect" of market-driven environmental regulations, while also guiding the shift towards cleaner industries in order to advance the level of eco-industrialization in URYR.

Thirdly, there is a need to enhance public knowledge regarding the involvement of the public in environmental governance. First and foremost, it is imperative to enhance public consciousness regarding environmental concerns and promote the notion of eco-friendly and sustainable lifestyles among the general population. Secondly, the public should be guided and nurtured in their willingness to consume green or ecological products and so on. Then, the government can give certain policy support to encourage, support and regulate the construction and development of civil environmental protection organisations. Furthermore, it is crucial to enhance the pertinent legislation and regulations concerning civil environmental protection organizations to enable them to effectively contribute to environmental governance and safeguarding.

Fourthly, there should be a hastened acceleration of the industrial structure upgrade in URYR. First and foremost, it is imperative to actively advocate for the reconfiguration of investment allocation, channeling capital towards the ecological sector, facilitating the shift in industrial composition, and establishing conducive circumstances for the advancement of ecological industrialization. Secondly, make efforts to develop high-tech industries, use scientific and technological innovation to drive industrial structure transformation, and maximize the contribution of industrial structure change in advancing eco-industrialization. Then, subsidies and incentives will be implemented to support and guide enterprises to strengthen energy-saving and clean-technology transformation, and to promote the continuous upgrading and transformation of industries, so as to promote eco-industrialisation operations.

Fifthly, it is necessary to combine computer information technology, data centre construction, etc. with the upgrading of industrial structure to strengthen information technology empowerment and promote the efficient development of eco-industrialisation, so as to improve the level of eco-industrialisation in the upper reaches of the Yangtze River. First, provide intelligent decision support. Based on the analysis and modelling of environmental data, computer technology is used to construct an intelligent decision support system to develop optimal heterogeneous environmental regulation strategies. The collected environmental data are then collated, analysed and modelled, and the relationship between heterogeneous environmental regulation and eco-industrialisation is explored using methods such as data mining and machine learning in computer technology. Furthermore, strengthening the level of arithmetic power will help to expand and strengthen the digital economy and promote high-quality and green development in the region. For example, promoting the construction of an integrated arithmetic network in the upper reaches of the Yangtze River, giving full play to the advantages of the upper reaches of the Yangtze River in terms of resources and the environment, and guiding the clustering of data centres in resource-rich areas in the upper reaches of the Yangtze River, which will in turn strengthen the exchange of information on the production, supply and consumption of eco-products, and assist the development of eco-industrialisation in the upper reaches of the Yangtze River.

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