An Empirical Research on the Relationship Between Comprehensive Utilization of Waste Resources and Environmental Governance

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Abstract. The development of comprehensive utilization of waste resources is an important part of the development of circular economy and the construction of a resource-cycling society. Using the empirical research method of multiple linear regression, this paper selects panel data from 30 provinces, autonomous regions, or municipalities directly under the central government of China from 2012 to 2021 to investigate the effects of the industry's development of comprehensive utilization of waste resources on the emission of pollutants in the environment. With common industrial solid wastes utilized and legal person capital as the main explanatory variables and total nitrogen oxide emissions as the explanatory variables, SPSSAU is utilized to empirically analyze the above factors. It concludes that the overall amount of nitrogen oxide emissions will increase by 51.356 tons for every 10,000 tons increase in the amount of common industrial solid wastes utilized extensively, which may be due to the imperfect technology of production and treatment facilities, mismanagement by the regulatory authorities, and the fact that solid wastes contain relevant substances and thus unavoidably produce emissions, resulting from the above three reasons. for every 1 unit increase in the square of legal person capital. The total amount of nitrogen oxides emission will be reduced by 66.75 tons, which can significantly reduce the emission of nitrogen oxides. In this paper, the model is considered robust by replacing the explanatory and interpreted variables in the robustness test.

Keywords: Utilization of Resources, Environmental Governance, Regression Analysis.

1. Introduction

To achieve the goal of carbon peaking and carbon neutrality, the 14th Five-Year Plan for Circular Economy Development emphasizes that creating a circular economy is a crucial step in creating a low-carbon, green environment. The comprehensive utilization of waste resources industry is a key task of the circular economy, as it recycles and utilizes waste generated in production and life and transforms it into valuable resources, lowers pollution in the environment and increases the rate at which resources are used effectively.

The full utilization of waste resources industry can play a significant role in fostering the growth of the circular economy, creating a resource-intensive and environmentally conscious society, as well as lessening the strain on the environment by implementing reduction, reuse, and recycling. Not only does the industry's complete use of the resources generated by waste contribute to environmental preservation, but it also fosters economic growth. Song et al. pointed out that China's current economic development is still resource-oriented, and most of the provinces in China are faced with the problems of resource depletion and energy depletion [1]. Therefore, the reuse of waste resources is the key to solving resource problems and promoting economic development.

Research related to the comprehensive use of the industry for waste resources is broadly categorized into the following three aspects based on content. In terms of technology, industrial pollution is an important part of environmental pollution. Copper slag, as a potentially hazardous waste, needs to be recycled due to its economic benefits. Tian et al. summarized the recycling methods of copper slag, pointing out that research and development is concentrated on achieving high reprocessing efficiency, lower usage of energy, and reduced secondary pollution [2]. Zhang et al.

demonstrated through research that enhanced Fenton technology can treat textile wastewater more economically and effectively compared to ultrasonic AOP treatment [3]. Li et al. applied struvite crystallization, a technology that recovers phosphorus from wastewater by applying it to industry, which can use the precipitate as waste material or chemical raw material to alleviate phosphorus pollution [4]. Not only that, Ma et al. proposed the concept of zero solids emission-driven resource recovery based on the current bioprocesses for food waste and argued that the management concept of the food waste treatment process should be converted from a single goal to an integrated process where multiple goals are jointly oriented [5]. Yap et al. summarized the potential of Microalgae in environmental protection because it does not release substances harmful to aquatic organisms, it can be used to combat heavy metal pollution [6]. Because Microalgae can be used for wastewater treatment and carbon dioxide utilization, Chen et al. proposed cultural techniques and policies, and regulations for Microalgae, which will be put into the production of a circular economy to achieve sustainable development [7].

In terms of management, Herczeg et al. wanted to support the development of circular economy through collaborative supply chain management form, industrial symbiosis, a strategy to achieve collective benefits by utilizing wastes and by-products between industries [8]. Cheng et al. proved through the validation of the model that governmental reward and punishment mechanisms can increase the participation of urban construction contractors in waste resource utilization [9]. From the viewpoint of the industry, Tang et al. constructed an industrial circular economy evaluation index system to make an analysis of the industrial circular economy in each region of China and found that there are large regional differences, demonstrating the northwest region lagging well behind the rest of the nation, with the eastern region developing at the highest rate, and the middle and northeastern regions developing more slowly [10]. Cui et al. analyzed the phosphonyls recycling market assessed the market by quantifying policy interventions and concluded that synergistic effects of multiple policies are needed to promote solid waste recycling [11].

In conclusion, a great deal of research has been done by academics on the complete exploitation of waste resources, and the results have been productive. It is easy to discover, nevertheless, that the majority of studies focus on the advancement of technological innovation in the thorough utilization of waste resources and the suggestions of the industry's overall management and operation mode. These studies fail to consider the industry's production efficiency and the influence of its growth on the management of environmental pollutants, particularly in a shortage of pertinent quantitative research. Considering that at this stage, governments across China are strengthening their investment in environmental protection and governance, issuing policies to support the development of the fully use of the waste resources industry, and actively improving the environment. Therefore, this paper tries to study the impact of pollutant emissions from the perspectives of the economy of scale and effectiveness of waste resource use.

2. Methodology

2.1. Data Selection

The data in this paper are drawn from the China Industrial Statistical Yearbook, China Statistical Yearbook, China Environmental Statistical Yearbook, and China Economic Census Yearbook, considering the data's availability, continuity, and representativeness. The statistical yearbooks of each region are used to supplement any missing data. Panel data of 30 provinces, autonomous regions or municipalities directly under the central government (excluding Tibet, Hong Kong, Macao and Taiwan) in China from 2012 to 2021 are selected to conduct an empirical analysis of how the industry's development of comprehensive waste resource utilization has affected pollution control.

2.2. Variable Construction

In this paper, the total amount of pollutant emissions is chosen as an explanatory variable (see Table 1). The pollutants emitted by a region mostly are composed of particulate particles, nitrogen

oxides, sulfur dioxide, and common industrial solid waste. According to the study of Jin et al., each of the above indicators for responding to the state of environmental pollution is reasonable because there is no broad consensus on the indicators that comprehensively reflect the state of pollution in a region [12]. Considering the difficulty and consistency of obtaining data, the total amount of nitrogen oxide emissions in exhaust gases was selected as an explanatory variable to assess the regional pollution control situation.

Explanatory Variables are divided into two categories: efficiency of comprehensive utilization of pollutants and economy of scale. To address the effect of complete utilization of pollutants treatment level on the emissions of nitrogen oxides in the exhaust gas, this paper uses the comprehensive utilization of common waste from industries to measure the amount of solid waste extracted or transformed from solid waste into energies, resources, and other unprocessed materials that can be utilized. The economy of scale is measured by the legal person capital of the waste resources comprehensive utilization industry in the provincial area, and the legal person capital is taken as its square, to indirectly reflect the cost-effectiveness brought by the expansion of enterprise scale to the waste resources comprehensive utilization industry.

There are many factors affecting pollution control, the control variables in this article are selected from five aspects, enterprise size using the logarithmic treatment of total assets, representing the industry's company size; the level of regional economic development to select the GDP index to react to the overall economic scale of the region and the trend of economic growth; the degree of environmental risk level using the number of emergency environmental events to show the stability of the environment; the human resources situation of the industry to take average number of employees to reflect the human resources scale of enterprises and management capacity; the total annual treatment using nitrogen-oxygen centralized pollution control facilities in the exhaust gas to measure the effect of pollutant emission reduction. The environmental risk level adopts the number of emergency environmental events to show the stability of the environment; the human resource status of the industry adopts the average number of employees to reflect the enterprise's human resource scale and management capacity; the total annual treatment volume utilizes the nitrogen and oxygen centralized pollution control facilities to measure the pollutant emission reduction effect in the exhaust gas.

Table 1. Variable description

Type	Variable Meaning	Variable Name	Symbol	Explanation
Explained Variable	pollutant emissions	nitrogen oxides emission	NO	total nitrogen oxide emissions at provincial level
Explanatory Variables	economies of scale	legal person capital	capital	legal person capital squared
	comprehensive utilization efficiency of waste resources	common industrial solid wastes utilized	ISWU	annual comprehensive utilization volume of common industrial solid waste at the provincial level
Control Variables	enterprise size	company size	size	natural logarithm of total provincial assets
	regional economic development level	GDP index	gdp	GDP at constant prices during the reporting period ÷ GDP at constant prices during the base period × 100 (previous year = 100)
	environmental risk level	number of emergency environmental events	env	annual number of environmental emergencies at the provincial level
	Human resources	average number of employees	employee	annual average number of employees at the provincial level
	total annual processing volume	centralized pollution control facility	facility	pollutant treatment volume of centralized pollution control facilities for nitrogen oxides in exhaust gas is calculated as the natural logarithm

2.3. Modelling

The data in this paper are processed using SPSS, with missing values filled in using the mean of the results of the multiple interpolation method and outliers filled in with the median. Based on previous studies, this paper constructs a multiple linear regression model from the mechanism of resource utilization efficiency and economy of scale of enterprises on the effect of the industry's comprehensive use of waste resources on the efficiency of pollution control, as follows.

$$NO_{it} = \beta_0 + \beta_1 capital_{it} + \beta_2 ISWU_{it} + \beta_3 size_{it} + \beta_4 gdp_{it} + \beta_5 env_{it} + \beta_6 employee_{it} + \beta_7 facility_{it} + \varepsilon \quad (1)$$

Among them, NO_{it}, $capital_{it}$, $ISWU_{it}$, $size_{it}$, gdp_{it}, env_{it}, $employee_{it}$, $facility_{it}$ respectively represent the amount of nitrogen oxides generated in the exhaust gases, legal person capital, common industrial solid wastes utilized, company size, regional economic development level, average number of employees, and the amount of pollutants treated by centralized pollution control facilities for nitrogen oxides in exhaust gases in area *i*, year *t*, respectively. β_0 represents the intercept term, β_1—β_7 are the estimated coefficients of the corresponding variables, ε is the residual error.

2.4. Robustness Check

By altering out the explanatory and interpreted variables, the robustness of the findings from empirical studies is confirmed in this work. To test the economy of scale in the independent variables, we replaced legal person capital with capital from Hong Kong, Macao, and Taiwan. However, we found that the negative data filled in by Hong Kong, Macao, and Taiwan capital when missing values are added are not meaningful in practice. Therefore, we treated the absolute value and denoted it by capital_HMT, as shown in equation (2). We used the absolute value of capital_HMT for the specific test, also shown in equation (2). This approach allows us to better understand the impact of these variables and draw more meaningful conclusions. The term "common industrial solid waste" describes industrial solid waste without hazardous qualities that isn't on the National Hazardous Waste List. The comprehensive utilization of hazardous solid waste (HWU), which is a comprehensive measure of the impact of the comprehensive utilization of solid waste on the management of pollutants, takes the place of the comprehensive utilization efficiency of pollutants. Equation (3) illustrates the specific test.

Dependent variable to study the degree of pollution control of the environment, hazardous waste as a class of solid waste, in the robustness test, the general industrial solid waste generation (CIS) and the total sulfur dioxide emissions (SO_2) were selected as alternative variables to supplement the robustness of the model's empirical effects on solid waste and other pollutants of the exhaust gases, and the specific tests are shown in equations (4) and (5), respectively.

3. Empirical Results

3.1. Descriptive Statistics

Prior to the empirical analysis, descriptive statistics were conducted on 300 samples from 30 provincial regions from 2012 to 2021, and the results are shown in Table 2. The 30 province-level regions of China exhibit significant variations in their emission levels of nitrogen oxides, with an average total of 527,730.553 tons, a standard deviation of 369,604.773, a lowest value of 38,315 tons, and a maximum of 1,761,110 tons, according to observations. Common industrial solid waste generation ranges from 1.94 million tons at the minimum to 520.37 million tons at the maximum, with an average of 122.256770 million tons and a standard deviation of 10,449.925. The average total emission of sulfur dioxide was 367,443.03 tons, with a standard deviation of 360,960.779, not much different from that of nitrogen oxides, but with a minimum value of 1,422 tons and a maximum value of 1,748,807 tons.

Comparably, when it comes to explanatory variables, the effectiveness of using legal person capital and pollutants comprehensively differs significantly and regionally. With a standard deviation of 5,265.554 and an average complete usage of 70.246 million tons, common industrial solid waste has a minimum value of 1.14 million tons and a maximum value of 252.3 million tons. Hazardous waste average comprehensive utilization of 1.62055 million tons, the standard deviation of 189.735, the minimum value of 0.001 million tons, the maximum value of 10.461 million tons. Legal person capital the minimum value of 0, the maximal value of 9,009.806, the standard deviation of 720.55, each region has a large gap. Between 0.02 billion and 12.545 billion yuan, there is not much of a difference in the average capital worth of 1.843 billion yuan shared by Hong Kong, Macao, and Taiwan.

Enterprise size, regional economic growth, and total annual volume of treatments all showed a small variance regarding the control variables. The distribution appears more balanced, with the mean enterprise size of 3.733, the minimum value of 0.068, the greatest value of 6.387, and the median of 3.98. The minimum and highest values of the GDP index are 95 and 113.6, respectively, while the average is 107.426 with a standard deviation of 2.544, which is not a big difference. The average treatment capacity of centralized pollution control facilities is 4.587, the standard deviation is 1.819, and the maximum value is 9. 047.For the rest of the control variables, the average risk level of the environment is 13.47, the maximal value is 251, the minimal value is 1, and the median is 8, which indicates that there is still a lack of environmental governance capacity in the regions, and that the emergency response system is not reasonable. The median of average number of employees is 3500, the average value is 6050 million, and the maximum value is 45,000, which indicates that the comprehensive utilization of waste resources industry is unevenly developed in each region.

Table 2. Summary statistics

Variables	N	Minimum	Maximum	Mean	Standard Deviation	Median
ISWU	300	114	25230	7024.6	5265.554	5461
HWU	300	0.1	1046.1	162.055	189.735	91.9
capital	300	0	9009.806	252.003	720.55	22.279
capital_HMT	300	0.02	12.545	1.843	2.01	1.172
size	300	0.068	6.387	3.733	1.331	3.98
gdp	300	95	113.6	107.426	2.544	107.7
env	300	1	251	13.47	23.041	8
employee	300	0	4.5	0.605	0.739	0.35
facility	300	0	9.047	4.587	1.819	4.745
NO	300	38315	1761110	527730.553	369604.773	435593
CIS	300	194	52037	12225.677	10449.925	9342
SO_2	300	1422	1748807	367443.03	360960.779	227648.5

The correlation study on the chosen variables in this article is done using SPSSAU, and Table 3 displays the findings. At the 5% level, there is a negative association between the total amount of nitrogen oxide emissions and legal person capital, and a strong positive correlation between the total amount of emissions and the comprehensive utilization of common industrial solid waste. There is a positive correlation between utilizing common industrial solid waste in all its components and legal person capital, with a correlation coefficient of 0.061, indicating that the relationship between the two is very weak and there are no multiple common problems. By measuring the variance inflation factor, it was found that the VIF of each variable was less than 5, that is, there was no collinearity problem in the sample data and it was suitable for regression analysis.

Table 3. Correlation matrix

	VIF	NO	ISWU	capital	size	env	gdp	employee	facility
NO	2.667	1							
ISWU	2.509	0.699**	1						
capital	1.155	-0.042	0.061	1					
size	2.358	0.165**	0.196**	0.291**	1				
env	1.087	0.083	-0.092	-0.008	0.064	1			
gdp	1.213	0.179**	-0.061	-0.022	-0.128*	0.094	1		
employee	2.366	0.288**	0.115*	0.264**	0.689**	0.095	0.018	1	
facility	1.743	0.128*	0.229**	0.118*	0.572**	0.116*	-0.273**	0.480**	1

Note: ***, **, * indicate significant at 1%, 5%, and 10% levels respectively.

3.2. Regression Results

Table 4. Regression results

	Eq. (1)
constant	-2289980.778** (-3.740)
ISWU	51.356** -19.63
captial	-66.750** (-3.447)
size	-30820.000* (-2.032)
gdp	23714.886** -4.262
evn	1910.598** -3.245
employee	172983.627** -6.749
facility	-19431.820* (-2.036)
N	300
R^2	0.625
Adjust R^2	0.616
F-value	F (7,292) =69.522, p=0.000

Table 4 shows the results of a regression analysis of the specified variables performed in this paper using the SPSSAU. The multiple linear regression has an F-value of 69.522 and a P-value of 0.000 < 0.01, which indicates that the model passes the test at the 1% significance level and the linear relationship of the equation overall is significantly established. The significance of the individual coefficients can be seen through the empirical study of integrated waste resource utilization industry and pollutant management, and further, the following findings can be made.

First, the coefficient of ISWU is 51.356, which means that for every 10,000 tons increase in the volume of comprehensively used common industrial waste that is solid, overall nitrogen oxide emissions will increase by 51.356 tons. With a P-value of 0.000<0.01, ISWU satisfactorily passes the test with a 1% significance level. For this research result, this paper has the following three speculations: firstly, there may be technical imperfections in the treatment facilities of general industrial solid waste, resulting in additional nitrogen oxides emissions during the treatment process. Second, the presence of the nitrogen oxides or substances related to them in some of the wastes contained in the general industrial solid wastes caused an increase in nitrogen oxides emissions during the treatment process. Thirdly, the lack of a sound system of waste regulation and control, possibly

due to mismanagement by environmental regulators, has resulted in increased emission of nitrogen oxides.

The coefficient for the second explanatory variable, legal person capital, is -66.75, which indicates that the total volume of nitrogen oxide emissions will decrease by 66.75 tons for every unit increase in the square of legal person capital. The P-value of legal person capital is 0.001<0.05, passing the significance test level of 5%. It implies that increasing the input of legal person capital, the size of the industry, and the production of waste resources comprehensive utilization industry leads to a reduction in nitrogen oxide emissions.

The DW value of the multiple linear regression model is 0.967, indicating a slight positive autocorrelation in the model, which suggests that there may be some variables that are not considered in the model, such as seasonal factors or time-series trends, which may affect the regression results of the model to some extent.

3.3. Robustness Analysis

Table 5. Results of robustness check

	explanatory variables are replaced		explained variable is replaced	
	Eq.(2)	Eq.(3)	Eq.(4)	Eq.(5)
Explained variable	NO	NO	CIS	SO_2
constant	-2230165.122** (-3.581)	-2800182.643** (-3.057)	56026.555** -4.364	-4196100.708** (-5.876)
ISWU	50.930** -19.158		1.779** -32.418	36.757** -12.046
HWU		449.778** -3.772		
capital		-67.040* (-2.324)	-0.225 (-0.553)	-68.864** (-3.049)
capital_HMT	12954.317 -1.804			
size	-38968.929* (-2.568)	-23827.437 (-1.033)	115.293 -0.362	-67005.284** (-3.787)
env	1950.582** -3.266	980.068 -1.116	-3.078 (-0.249)	1576.883* -2.296
gdp	23202.532** -4.097	30258.876** -3.629	-491.940** (-4.216)	43517.492** -6.705
employee	155766.391** -5.937	157245.558** -4.122	-1416.498** (-2.635)	126231.746** -4.222
facility	-19906.306* (-2.032)	428.373 -0.03	-637.201** (-3.184)	-43527.495** (-3.910)
N	300	300	300	300
R^2	0.614	0.171	0.794	0.465
Adjust R^2	0.605	0.151	0.789	0.452
F-value	F(7, 292)=66.365, p=0.000	F(7, 292)=8.574, p=0.000	F(7, 292)=160.477, p=0.000	F(7, 292)=36.265, p=0.000

There are four ways to ensure the stability of the experimental results: (1) Hong Kong, Macao and Taiwan capital are used to replace the legal person capital, and all other variables remain unchanged in the regression, and the specific regression results are presented through equation (2). (2) The amount of hazardous waste disposal instead of the amount of general industrial solid waste utilization, and all other variables remain unchanged in the regression. The specific regression results are presented through equation (3). (3) Common industrial solid waste generation instead of the total amount of nitrogen oxides emissions, equation (4) presents the unique regression findings, while the other variables remain unaltered. (4) The total amount of sulphur dioxide emissions instead of the

total amount of nitrogen oxides emissions, other variables are unchanged for regression. The specific regression results are presented through equation (5).

Table 5 displays all the empirical outcomes to the robustness test, Hong Kong, Macao and Taiwan capital in equation (2) is not significant and the sign changes, which may be due to the failure to consider the impact of external factors, such as changes in the macroeconomic environment, policy adjustments and so on. Equation (3) in the company size and number of emergency environmental events sign is unchanged but not significant; centralized pollution control facilities sign and significance are changed. This may be due to the fact that the correlation between the amount of hazardous waste comprehensive utilization and disposal and company size and number of emergency environmental events is not high, and there are some complex relationships with centralized pollution control facilities, which leads to the change of these three variables and the decrease in the explanatory strength of the model. Secondly, since the correlation coefficient between centralized pollution control facilities and company size is 0.572 and significantly positive at 5% level, it leads to insignificant company size when replacing the explanatory variables. Equation (4) compared to the original model, the sign of enterprise size becomes positive, number of emergency environmental events sign becomes negative and both are insignificant along with legal person capital, which may mean that firms with large company sizes require more complex treatment procedures and handle more wastes, which, together with technological The increase in number of emergency environmental events may increase the company's management and monitoring of the production process, which may have a negative inhibitory effect on the generation of solid waste. In addition, there may be some correlation between general industrial solid waste and legal person capital or after replacing the dependent variable, the explanatory power of other variables on the amount of general industrial solid waste generated increases, due to the complex correlation between the variables, so that the explanatory power of legal person capital on the dependent variable after replacement decreases, and thus is not significant. significant. In Equation (5), the signs of all independent variables and control variables on total sulfur dioxide emissions remain consistent with the original model, and all are significant. Thus, the robustness tests of all four methods show that the estimation effect of the above model is robust and reliable.

4. Conclusion

The recycling and reuse of waste pollutants can help China develop a circular economy and create society that is environmentally conscious and utilizing resources effectively. Pollutants treatment is significantly impacted by the developing of the waste resource comprehensive use industry. The following are the study findings presented in this article: (1) Comprehensive utilization efficiency of pollutants has a promoting effect on the emission of pollutants; (2) The economies of scale in the comprehensive utilization of waste resources industry have a positive inhibitory effect on the emission of pollutants.

Based on the findings in the above two aspects, this paper concludes that there are the following limitations in the development of the waste resource comprehensive utilization industry: (1) There are technical deficiencies in waste resource treatment facilities, which leads to waste resources causing pollution again during the recycling process. It aggravates environmental pollution and requires the industry to invest in research and development funds and training of relevant staff to ensure the effective recycling of pollutants. (2) The imperfect monitoring of the production process of the comprehensive utilization of waste resources industry, as well as the lack of a complete environmental supervision system and environmental emergency incident handling system by the environmental management department, have resulted in the lack of effective control of environmental pollution incidents in some areas, which requires various regions to To strengthen awareness of environmental management and testing, local governments need to provide policy preferences in technology research and development for pollution prevention, pollutant treatment and regulatory implementation to promote industry development.

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