



# Study on the Relationship between Industrial “Three Wastes” and Economic Growth in Guangzhou

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**Abstract.** Industry stimulates economic development but also pollutes the environment, so it is socially significant to investigate whether there is a harmonious development between industrial “Three Wastes” and economic growth from the perspective of industry. In this paper, a time series of data from 2002 to 2021 is selected for Guangzhou, with environmental variables as the dependent variables and economic variables as the independent variables, and an empirical analysis of variance decomposition is conducted based on the VEC model to investigate the unidirectional and interrelationship between industrial “Three Wastes” and economic growth in Guangzhou. The results show that, based on the VEC model, the variance decomposition results indicate that the impact of industrial “Three Wastes” on economic growth in Guangzhou is greater than the impact of economic growth on industrial “Three Wastes”. Finally, based on the empirical results, suggestions such as optimizing and upgrading the industrial structure, strengthening the prevention and control of industrial wastewater, and insisting on developing a green economy are proposed.

**Keywords:** Industrial “Three Wastes”, Economy growth, VEC model, Guangzhou.

## 1 Introduction

Guangzhou, the capital of Guangdong Province, is a highly developed city in China. Its gross regional product has been steadily increasing until 2021. However, the emissions of industrial waste gases continue to rise, while industrial wastewater emissions have been decreasing since 2008. The generation of industrial solid waste shows fluctuating changes.

Scholars at home and abroad have extensively studied the relationship between environmental quality and economic growth. The Environmental Kuznets Curve (EKC) was proposed in the 1990s [3], and its existence has been verified by various researchers [2, 6, 9, 11]. In addition, some scholars have found that not all regions have an inverted “U” curve between the economy and the environment. Sanghoon Lee et al. [10] used a fixed effects model and sample partitioning to examine Chinese municipal panel data and found an “N” shaped relationship between per capita income and pollution.

Yingshan Li [14] and Yongchang Shen [15] found that the relationship between environmental quality and economic growth in some provinces and municipalities in China does not fully conform to the inverted “U” curve. Some scholars also use other research methods to analyze the relationship between environmental quality and economic growth. Melike [8], Lin Hongru [4] and Yichen Liu [13] used the VAR model to analyze the interrelationship between environmental pollution and economic growth. Yang Siqu et al. [12] used factor analysis and regression analysis to study and demonstrate the relationship between economic development and environmental quality in Guangdong Province, and the study showed that economic growth can improve the environmental quality of the region. Hui Zhang et al. [5] used principal component analysis to analyze the relationship between the economy and the environment in the eastern region of China (Jiangsu, Zhejiang, and Shanghai Provinces) and found that there is an inverted “U” relationship in all three provinces.

In conclusion, in different regions and stages of economic and social development, the relationship between economic growth and environmental quality (or pollution) varies. Therefore, analyzing the connection between economic growth and industrial “Three Wastes” in Guangzhou will contribute to the understanding of economic growth and environmental quality. This research will also provide insights and recommendations for promoting the coordinated development of the environment and the economy in Guangzhou, as well as other similar cities. When it comes to research perspectives, more scholars analyze the economy-environment relationship at the country or regional level using the EKC model, while fewer studies focus on the municipal level. Economic indicators such as growth, industrial structure, and urbanization rate are commonly used, while environmental quality indicators include industrial “Three Wastes” and air pollutants. The VAR model is frequently used to analyze the interrelationship between economic growth and the environment, but there is limited empirical evidence based on the VEC model. Based on previous research and the characteristics of the selected data, this study will focus on Guangzhou. The research will primarily examine the relationship between per capita GDP (independent variable) and industrial “Three Wastes” (dependent variable) using the EKC fitting and VEC model. The study aims to analyze the unidirectional and mutual relationship between environmental quality and economic growth in Guangzhou.

## 2 Research methods

### 2.1 Data selection and pre-processing

In this paper, the time series data of GDP per capita and industrial “Three Wastes” of Guangzhou in 2002-2021 are selected for examination. To eliminate price differences, the per capita GDP in 2000 is used as the base period, and the per capita GDP index is used to adjust the per capita GDP (yuan/person) in 2002-2021, which is denoted as *pgdp*; and the environmental indicators, such as industrial wastewater emissions (10,000 tons), industrial emissions (100 million cubic meters), and the amount of industrial solid waste generated (10,000 tons), are denoted as *water*, *air*, and *solid*, respectively. Among them, the data on economic indicators come from the Guangzhou

Statistical Yearbook, and the data on environmental indicators come from the Guangzhou Environmental Protection Bureau, Guangzhou Environmental Bulletin, and Guangzhou Statistical Yearbook.

To make the measurements consistent, the data are normalized as in Eq. (1), and the processed economic and environmental indicators are *igdp*, *fs*, *fq*, *gf*, and *ei*, respectively.

$$Z = (Z_{max} - Z_i)/(Z_{max} - Z_{min}) \tag{1}$$

Where *Z* denotes the variables substituted for performing the normalization calculation.

The coefficient of variation method was utilized to obtain the composite indicator of environmental quality (*ei*), which was calculated as shown in equations (2) and (3).

$$B_m = S_m/X_m \tag{2}$$

$$ei = Y \cdot B_m \tag{3}$$

where *B<sub>m</sub>* is the coefficient of variation of an indicator, *S<sub>m</sub>* is the standard deviation of an indicator, and *X<sub>m</sub>* is the mean of an indicator. *Y* is the result after the normalization of an environmental indicator, and *B<sub>m</sub>* is the coefficient of variation of an indicator.

The names of each variable involved above and the corresponding symbols and units are shown in Table 1.

**Table 1.** Indicator names and symbols

variable name	variable symbol	unit	variable name	variable symbol	unit
GDP per capita	<i>pgdp</i>	yuan	Normalized GDP per capita	<i>igdp</i>	1
Industrial waste water emissions	<i>water</i>	10 <sup>4</sup> tons	Normalized industrial waste water emissions	<i>fs</i>	1
Industrial waste gas emissions	<i>air</i>	10 <sup>8</sup> m <sup>3</sup>	Normalized industrial waste gas emissions	<i>fq</i>	1
Industrial solid waste generation	<i>solid</i>	10 <sup>4</sup> tons	Normalized industrial solid waste generation	<i>gf</i>	1
			Composite index of environmental quality	<i>ei</i>	1

## 2.2 EKC model and VEC model

In order to test the validity of the data, before modeling, the variables will be tested for smoothness and cointegration. Then, the EKC simplified model and the VEC model are used to empirically analyze whether the relationship between industrial “Three Wastes” and economic growth in Guangzhou is consistent with the environmental Kuznets curve, and the degree of interaction between the two.

**EKC simplified model.** Drawing on the research results of Liu Yuanshu et al. [7] and Xia Baichuan [1], ignoring the influence of other factors on the model, a simplified model of the EKC curve is established, which can be selected from the primary, secondary and tertiary equations. Each equation is shown in Eqs. (4)-(6):

$$Y = \beta_0 + \beta_1 pgdp \quad (4)$$

$$Y = \beta_0 + \beta_1 pgdp + \beta_2 pgdp^2 \quad (5)$$

$$Y = \beta_0 + \beta_1 pgdp + \beta_2 pgdp^2 + \beta_3 pgdp^3 \quad (6)$$

Where,  $Y$  refers to an industrial “Three Wastes” emissions,  $\beta_0$  is a constant term,  $\beta_1$ ,  $\beta_2$ ,  $\beta_3$  are regression parameters,  $pgdp$  is an economic indicator. With the help of SPSS software, the environmental indicators *water*, *solid*, *air*, and economic indicators  $pgdp$  were fitted with the EKC curve.

**Vector error correction model (VEC).** VEC was proposed by Engle and Granger (1987) and applied to systems with cointegration relationships. The premise of the VEC model is that there is a cointegration relationship between the variables, so the VEC model is a cointegration-constrained VAR model, which is mostly applied to the error correction of unstable time series. Error Correction. The model can capture the long-run equilibrium relationship and the short-run dynamic adjustment relationship between non-stationary time series; by introducing the difference term and the error correction term, the correlation between the variables can be eliminated and the estimation accuracy can be improved. The VEC model formulas here are set up as shown in equations (7) and (8):

$$\Delta Y = \alpha ecm_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \varepsilon \quad (7)$$

$$ecm_{t-1} = \beta Y_{t-1} \quad (8)$$

In Eq. (7), the magnitude of  $\alpha$  reflects the strength of the adjustment required to bring the variable to equilibrium when it deviates from equilibrium.  $ecm_{t-1}$  is the error correction term.  $\sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i}$  is the difference term for all explanatory and interpreted variables, and the coefficient reflects the effect of short-term changes between the variables on the short-term changes in the interpreted variables.

Eq. (8) is the error correction vector, i.e., the cointegration equation, which reflects the long-run equilibrium relationship between the variables.  $\beta$  is the cointegration vector, which represents the relationship between the variables and the magnitude of changes.

### 3 Results and discussion

#### 3.1 ADF test

To eliminate the occurrence of “pseudo-regression”, this paper will carry out the smoothness test on the selected data, and the results show that the variables at the 5% significant level, the 0th-order monotonic are: *gf*, the 1st-order monotonic are: *igdp*, *ei*, *fs*, *fq*, *water*, *solid*, *air*. Therefore, the variable *gf* is excluded.

#### 3.2 EKC model analysis

The results of the most appropriate equations for fitting the EKC curves for the environmental indicators *water*, *solid*, *air*, and the economic indicator *pgdp* are shown in Table 2 below.

**Table 2.** Results of fitting industrial “Three Wastes” to *pgdp*

Environmental indicators	model summary			Equation	figure of a curve
	R <sup>2</sup>	F	P		
<i>water</i>	0.584	11.936	0.001	<i>water</i> = 5755.228 + 0.620 <i>pgdp</i> - (5.070E - 06) <i>pgdp</i> <sup>2</sup>	inverted U-shape
<i>air</i>	0.871	57.640	0.000	<i>air</i> = 3886.845 - 0.0756 <i>pgdp</i> + (8.333E - 07) <i>pgdp</i> <sup>2</sup>	N-shape
<i>solid</i>	0.585	7.517	0.002	<i>solid</i> = 241.529 + 0.010 <i>pgdp</i> - (6.441E - 08) <i>pgdp</i> <sup>2</sup> + (3.772E - 12) <i>pgdp</i> <sup>3</sup>	inverted U-shape

From the EKC curve regression results, the relationship between industrial “Three Wastes” and *pgdp* in Guangzhou is not fully consistent with the traditional EKC curve shape. Among them, industrial wastewater and GDP per capita are in the shape of a traditional inverted “U” curve, while industrial solid waste and GDP per capita are in the shape of a positive “N” curve, and industrial waste gas and GDP per capita are in the shape of a positive “U” curve. industrial waste and GDP per capita have a positive “U” curve shape. This shows that the current economic growth of Guangzhou has a different trend of influence on its industrial “Three Wastes” emissions.

#### 3.3 VEC model analysis

**Johansen cointegration test.** The optimal lag order of the original series *solid* and *pgdp* is chosen as the 1st order at the 0.05 significant level, and the optimal lag orders of the normalized indicators *ei*, *fs*, *fq*, and *igdp* are chosen as the 1st order, 1st order, and 3rd order respectively. On this basis, this paper will carry out the Johansen cointegration test for the environmental and economic indicators with the same order of monotonicity, and the results show that there is one cointegration relationship between *fs*,

$fq$ , and  $igdp$  at the 0.05 significant level. At the 0.1 level of significance, and according to the number of cointegration relationships (number of variables-1), there is one cointegration relationship between  $igdp$  and  $ei$ ,  $pgdp$ , and  $solid$ . This shows that  $solid$  has a long-run equilibrium relationship with  $pgdp$ ;  $ei$ ,  $fs$ , and  $fq$  have a long-run equilibrium relationship with  $igdp$ . Therefore, in this subsection, the short-run equilibrium between the quality of the environment and economic growth is investigated by using the vector error correction (VEC) model to analyze the short-run and long-run effects between the variables.

**Error correction modeling results.** The following covariance equations were obtained by running the Eviews software as Eqs. (9)-(12):

$$ei\ ecm_{t-1} = ei(-1) + 1.1177 \times igdp(-1) - 1.2104 \quad (9)$$

$$fs\ ecm_{t-1} = fs(-1) - 1.0399 \times igdp(-1) - 0.0369 \quad (10)$$

$$fq\ ecm_{t-1} = fq(-1) + 1.0628 \times igdp(-1) - 1.2964 \quad (11)$$

$$solid\ ecm_{t-1} = solid(-1) + 0.0036 \times pgdp(-1) - 848.0231 \quad (12)$$

To summarize, industrial wastewater emissions are positively correlated with GDP per capita in Guangzhou, while the environmental quality composite index, industrial exhaust emissions, and industrial solid waste emissions are negatively correlated with GDP per capita. From a general point of view, environmental pollution decreases with economic growth in Guangzhou, so economic growth may improve environmental quality. However, it is worthwhile to emphasize that since there is a positive correlation between industrial wastewater and GDP per capita, i.e., industrial wastewater emissions will increase with economic growth. On the one hand, the formation and development of urbanization are driven by industrialization, and on the other hand, the industry in Guangzhou is mainly dominated by industries with high water demand, such as printing & dyeing and wine-making, so this mechanism of industrialization produces a large amount of industrial wastewater.

**Variance Decomposition.** Variance decomposition is the study of the extent to which the fluctuations of a series are affected by its shocks, as well as the extent of shocks generated by other factors in the model, and can be used to evaluate the importance of different shocks to the explanatory variables. In this paper, we will analyze the variance decomposition of  $solid$  with  $pgdp$ ,  $ei$ ,  $fs$ ,  $fq$  with  $igdp$ .

The results of the variance decomposition analysis in Table 3 shows that the explanation of environmental indicators to per capita GDP gradually increases, in which the biggest influence on per capita GDP of Guangzhou is industrial wastewater emissions, indicating that the influence of the environmental pollution problem of Guangzhou, which leads to the decline of environmental quality on economic growth, will gradually increase, as well as the economic growth of Guangzhou, which is built based on the increase of industrial wastewater emissions. From the overall point of view, the explanation of environmental indicators to GDP per capita is larger than the explanation of

GDP per capita to environmental indicators, which shows that in the variance prediction, there is a mutual influence between industrial “Three Wastes” emissions and economic growth in Guangzhou, but the industrial “Three Wastes” emissions to economic growth in Guangzhou are more important than the environmental indicators to economic growth in Guangzhou. It shows that in the variance prediction, there is a mutual influence between industrial “Three Wastes” emission and economic growth in Guangzhou, but the influence of industrial “Three Wastes” emission on economic growth in Guangzhou is greater than the influence of economic growth on environmental pollution.

**Table 3.** Variance decomposition of *ei, fs, fq, solid, igdp* and *pgdp*

Phase	Variance decomposition of <i>ei, fs, fq</i> or <i>solid</i>				Variance decomposition of <i>igdp</i> or <i>pgdp</i>			
	Interpre- tation Strength of <i>igdp</i> on <i>ei</i>	Interpre- tation Strength of <i>igdp</i> on <i>fs</i>	Interpre- tation Strength of <i>igdp</i> on <i>fq</i>	Interpre- tation Strength of <i>pgdp</i> on <i>solid</i>	Interpre- tation Strength of <i>ei</i> on <i>igdp</i>	Interpre- tation Strength of <i>fs</i> on <i>igdp</i>	Interpre- tation Strength of <i>fq</i> on <i>igdp</i>	Interpre- tation Strength of <i>solid</i> on <i>pgdp</i>
1	9.010	0.991	32.850	0.077	9.010	0.991	32.850	0.077
2	9.415	1.278	33.360	0.057	15.089	18.549	32.694	1.644
3	9.815	1.587	33.381	0.125	21.105	34.039	47.119	4.653
4	10.207	1.907	33.737	0.277	26.645	44.681	53.675	8.062
5	10.592	2.233	33.760	0.502	31.565	51.817	53.914	11.354
6	10.968	2.560	33.844	0.787	35.855	56.722	55.892	14.320
7	11.335	2.884	33.844	1.119	39.567	60.209	53.008	16.906
8	11.692	3.204	34.206	1.486	42.772	62.767	51.567	19.126
9	12.041	3.518	34.082	1.877	45.541	64.699	48.652	21.022
10	12.380	3.825	34.945	2.285	47.940	66.195	45.575	22.640

## 4 Conclusions

First of all, from the EKC curve regression results of industrial “Three Wastes” and economic growth in Guangzhou, the economic development of Guangzhou has a different trend of influence on its industrial “Three Wastes” emissions, and thus different types of environmental pollutants should be formulated or adopted targeted environmental policies or systems. Therefore, for different types of environmental pollutants, it is necessary to formulate or adopt targeted environmental policies or systems. Secondly, from the VEC model, this paper argues that the Guangzhou government should pay attention to the prevention and control of industrial wastewater when encouraging the development of the economy and enterprises in the process of industrial production. Finally, the results of the variance decomposition analysis of industrial “Three Wastes” and economic indicators in Guangzhou show that the impact of industrial “Three

Wastes” on economic growth is greater than the impact of economic growth on industrial “Three Wastes”, so it is necessary to pay attention to the prevention and control of industrial wastewater. Therefore, it is necessary to pay attention to environmental protection, pollution prevention, and the coordinated development of environment and economy.

## 5 Recommendations

To promote the unified and coordinated development of environment and economy in Guangzhou, combined with the empirical results, this paper puts forward the following countermeasure suggestions for the contradiction between environmental quality and economic growth in Guangzhou:

First, optimize and upgrade the industrial structure and increase the proportion of the tertiary industry. Guangzhou has entered the “three, two, one” industrial structure mode, but the waste gas, wastewater, and solid waste produced by industry is still a big killer to human health and environmental quality. Therefore, encouraging the development of tertiary industry is conducive to promoting economic growth, reducing the consumption of environmental resources, and promoting the coordinated development of the environment.

Second, strengthen the prevention and control of industrial wastewater and optimize wastewater treatment in industrial parks. The economic growth of Guangzhou is based on the increase in industrial wastewater discharge, which is not conducive to the coordinated development of the environment and economy in Guangzhou. Therefore, the government supports and supervises enterprises or industrial parks to build centralized industrial wastewater treatment plants, which helps to improve the treatment efficiency, reduce the input cost of wastewater treatment, and realize the scientific prevention and control of industrial wastewater.

Third, insist on the development of a green economy and promote high-quality economic development. Improvement of environmental quality is not only for human health, but also particularly important for economic development, and good environmental quality will affect the quality of economic development. Adhere to the development of a green economy to lead the economy to high-quality development, is conducive to the economic transformation and industrial upgrading of Guangzhou.

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