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Relationship between Chemical Pollution and Regional Economic Development

Yixian Wen

Department of economics and management, hunan institute of technology, Hengyang 421002, China
bjwuzg@126.com

As the industrialization process continues to accelerate, the China's economy develops at a full speed. Unfortunately, it also arises a series of environmental pollution problems, and the pressure on resources and environment has become increasing severe. Chemical pollution has restricted residents to safely enjoy many benefits attributable to economic development. We should intensify the investigation on the relationship between chemical pollution and economic development since it indeed has important theoretical and practical implications. This paper uses panel data to positively analyze the relationship between the above two by establishing a simultaneous equations model. The findings show that the China's industrialization process accelerates in pace with dramatic development in the economy, which exacerbates the environmental pollution problems. The emissions of "three wastes" shows an upward trend year by year. The regression results from the chemical pollution equation show that the chemical pollution has a linear relation with the regional economic development. A significance test also passes. The regression results from the output equation show that the various indicators for chemical pollution all have a significantly negative impact on regional economic development, which suggests that the economic growth will be stunted with the increase in chemical pollution emissions; physical capital stock, human capital stock and labor inputs also play a significantly positive impact on the regional economic growth, which shows that these three can effectively drive the development of regional economy.

1. Introduction

As the industrialization process continues to accelerate, economic growth has led to an increase in the income level of residents, and the level of social welfare has also been greatly improved (Pu, 2017). However, in the process of continuously economic development, a series of environmental pollution problems have also arisen, which put enormous pressure on resources and environment. In particular, as economic development is driving forward, the chemical industry has also led to a growing number of pollution levels such as water, air and solid waste pollution (Gürlük, 2009). Chemical pollution has made it impossible for residents to safely enjoy many benefits created by economic development, the study of the relationship between chemical pollution and economic development, therefore, has important theoretical and practical significance (Chen, 2015).

On the relationship between environmental pollution and economic development, scholars at home and abroad have made extensive studies. These efforts have borne fruits, for example, some scholars conducted the survey on the factors that affect the environment quality (Liu et al., 2009; Mao et al., 2013; Lai et al., 2016); some scholars believe that there is a two-way relationship between the environmental quality and economic growth (Aunan et al., 2006; Vaidyanadhan, 2013); some also argue that there is no direct correlation between chemical pollution and economic development (Li et al., 2011; Billard, 1988). This paper uses panel data to positively analyze the relationship between chemical pollution and regional economic development by building a simultaneous equations model, thus providing the clues to the environmental governance and sustainable economic development.

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2. Relevant theories

2.1 Multiple linear regression analysis

Regression analysis is a mathematical statistics method for dealing with the statistical correlation between the variables. Its basic idea is to find a mathematical expression that can represent the relationship between independent and dependent variables. If there are two or more independent variables, it is called multiple regression (Wessel and Jurs, PC 1994).
Suppose Y is the dependent variable, X_1, X_2, …, X_k are independent variables. If there is a linear relationship between the independent and the dependent variables, then the multiple linear regression model is:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\cdots\beta_kX_k+\varepsilon \quad (1)$$

Where β_i is the regression parameter; εis the random error.
The linear regression model makes a sense of dividing Y into the deterministic and the non-deterministic parts (Bersten, 1998). In the practical analysis process, multiple observations are performed to obtain *n* sets of sample data (yi; xi1, xi2..., xip). The multiple linear regression model can be expressed as:

$$y_1=\beta_0+\beta_1X_{11}+\beta_2X_{12}+\cdots\beta_kX_{1p}+\varepsilon_1$$
$$y_2=\beta_0+\beta_1X_{21}+\beta_2X_{22}+\cdots\beta_kX_{2p}+\varepsilon_2$$
...
$$y_n=\beta_0+\beta_1X_{n1}+\beta_2X_{n2}+\cdots\beta_kX_{np}+\varepsilon_n \quad (2)$$

Formula (2) can be simplified to:

$$Y_i=\beta_0+\beta_1X_{i1}+\beta_2X_{i2}+\cdots\beta_kX_{ip}+\varepsilon_i \quad (3)$$

In multiple linear regression analysis, the fitting degree of the model needs to be tested to determine whether the model can be applied (Afantitis et al., 2006). In general, it is mainly determined by multiple determinants. The formula is:

$$R^2=\frac{SSR}{SST}=1-\frac{SSE}{SST}=1-\frac{\sum(y-\hat{y})^2}{\sum(y-\bar{y})^2} \quad (4)$$

Where, SSR is the regression sum of squares; SSE is the residual sum of squares; SST is the sum of squares of total deviations.
R^2 takes [0, 1]. The greater it takes, the stronger the fitting degree of sample data points of the regression equation, and the closer the relationship between the independent and the dependent variables (Clouser and Jurs, 1996). Since R^2 is more subjected to the number of independent variables, it usually needs to be adjusted. The specific method is to divide SSE and SST by their respective degrees of freedom, thus effectively weakening the effect of the number of independent variables on the fitting degree. The specific formula is:

$$R^2=1-\frac{\frac{\mathrm{SSE}}{\mathrm{n-k-1}}}{SST(n-1)}=1-(1-R^2)\frac{n-1}{n-k-1} \quad (5)$$

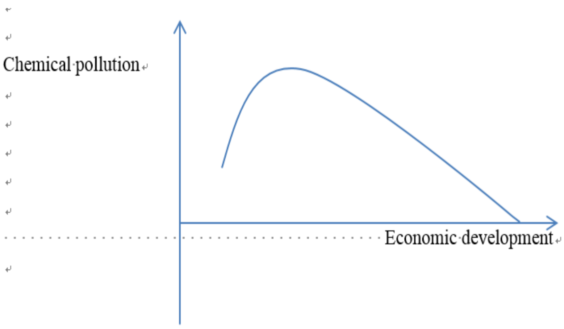
For the significance test of multiple regression equations, the F test is usually used, and the calculation formula is:

$$\mathrm{F}=\frac{SSR/k}{SSE/(n-k-1)} \quad (6)$$

The greater the value F, the change in the dependent variable subjected to the independent variable is higher than that in the independent variable caused by the random variable. Simultaneously, the F statistics can also reflect the fitting degree of the regression equation.
Looking up the F distribution list based on the given significance level and degree of freedom, the appropriate critical value Fa is available. If F > Fa, the regression effect is significant, the regression equation has significant significance; F < Fa, the regression effect is not significant, and the regression equation is meaningless (Shimada et al., 2000).

2.2 Theoretical analysis of the relationship between chemical pollution and regional economy

In the 1950s, environmental economists found that in the process of economic development, chemical pollution first deteriorated and then was improved, which readily subscribed to the theory proposed by Kuznets that the income gap first expanded and then narrowed in the process. Therefore, it is considered that there is also an inverted U type relationship between economic development and chemical pollution, as shown in Fig. 1.



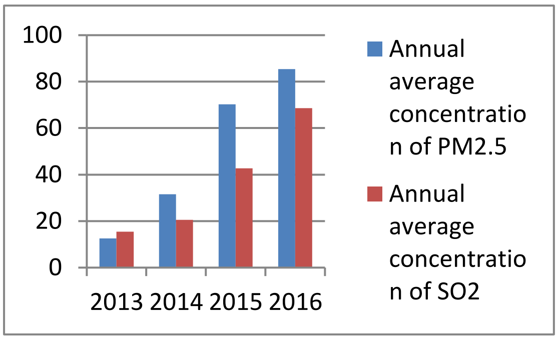


Figure 1: Environmental Kuznets District

Figure 2: Annual average concentration of SO_2 and PM2.5

3. Positive analysis of relationship between chemical pollution and regional economic development

3.1 Analysis of current situation of chemical pollution and economic development in China

Along with the rapid development of the economy, the speed of China's industrialization process has been accelerating, bringing with it the increasingly serious deteriorating environment pollution problems. The emissions of “three wastes” show an upward tendency year by year. On the whole, it is not optimistic about the situation. See Fig. 2, 3 and Table 1 for details.

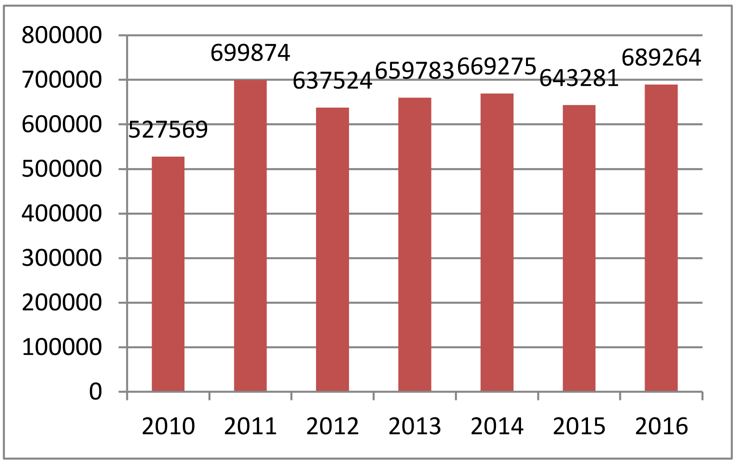


Figure 3: Total emission of industrial waste gas

Table 1: Industrial waste emissions

Year	Production of industrial solid waste	Industrial solid waste emissions
2010	88483	3697.2
2011	92679	2968.1
2012	126684	1976.3
2013	147237	1762.6
2014	196744	1287.3
2015	219746	726.3
2016	387629	628.9

3.2 Positive analysis

In the positive analysis of the relationship between chemical pollution and regional economic development, a joint model including pollution and output equations is built. Specifically, the chemical pollution equation is:

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 X_{it}^2 + \beta_3 X_{it}^3 + \beta_4 Z_{kit} + \varepsilon_{it} \quad (7)$$

The output equation is

$$X_{it} = \gamma_0 + \gamma_1 Y_{it} + \gamma_2 K_{it} + \gamma_3 H_{it} + \gamma_4 L_{it} + \vartheta_{it} \quad (8)$$

Where: Y_{it} represents the degree of chemical pollution, and is measured by the emissions of pollutants including "three wastes"; X_{it} represents the regional economic development level; K_{it},H_{it},L_{it} represent the capital, manpower and labor stock levels, respectively; ε_{it} and ϑ_{it} represent random error terms, respectively; *i* and *t* represent the region and time, respectively; *k* represents the number of impact factors. This paper chooses panel data between 2006-2016 in 30 regions of China (excluding Tibet) for positive analysis. The selected variables as indicators are shown in Table 2.

Table 2: Various indicators in empirical analysis

First class index	Second class index	Third class index
Chemical pollution index(A_1)	Water pollution(B_1)	Industrial wastewater discharge(C_1) Pollutants in industrial waste water(C_2)
	Air pollution(B_2)	Industrial dust emission(C_3) Industrial SO_2 emissions(C_4)
	Solid waste pollution(B_3)	Production of industrial solid waste(C_5)
Regional economic development indicators(A_2)	Level of economic development(B_4)	Gross Regional Product(C_6)
	Population size(B_5)	Population density(C_7)
	Level of science and technology(B_6)	The proportion of environmental research funds in the proportion of financial expenditure(C_8) The proportion of science and technology expenditure in the proportion of financial expenditure(C_9)
Other factors affecting pollution(A_3)	Industrial structure(B_7)	The second industry accounts for the proportion of GDP(C_{10})
	Energy utilization ratio(B_8)	Energy consumption of ten thousand yuan GDP(C_{11})
	Government environmental protection control(B_9)	The amount of the charge for discharge of sewage accounts for the proportion of GDP(C_{12}) Investment in industrial pollution control accounts for the proportion of GDP(C_{13})
Other output elements(A_4)	Stock of material capital(B_{10})	Fixed capital stock(C_{14})
	stock of human capital(B_{11})	Years of education for all employment personnel(C_{15})
	Labor input(B_{12})	Total number of employees at the end of the year(C_{16})

The joint equation model is regressed by MATLAB software, where the regression results of the chemical pollution equation are shown in Table 3.
From Table 3, it is found that chemical pollution has a linear relationship with regional economic development, which passes the significance test at the 1% significance level. In this sense, the economic development will exacerbate chemical pollution. It is required to intensify the pollution control while developing the economy, so as to achieve coordinated development between the economy and the environment. There is also no direct relationship between population size and chemical pollution. The government's environmental control, industrial structure and technological development level will only have a direct relationship with some chemical pollutants.
In parallel, the output equation is regressed by MATLAB software. The regression results are shown in Table 4.
From Table 4, it can be found that various chemical pollution indicators will produce a significantly negative impact on regional economic development, which shows that it will obstruct regional economic growth to a certain extent as chemical pollution emissions aggravate, and also to some extent that the growth model with high pollution and emissions is unsustainable. Besides, the physical capital stock, human capital stock and labor input have a positive impact on regional economic growth, and the significance test has passed, showing that these three can effectively push the development of regional economy.

Table 3: Estimated results of pollution equation

Pollution indicators	C_1	C_2	C_3	C_4	C_5
C	8.693 (15.741) ***	15.328 (18.961) ***	1.694 (2.754) ***	13.691 (18.592) ***	6.682 (2.917) ***
C_6	0.247 (3.358) ***	0.317 (3.674) ***	0.924 (22.616) ***	0.641 (0.824) ***	1.535 (2.947) ***
C_7	--	--	--	--	--
C_8	--	--	--	--	-0.018 (-2.627) ***
C_9	-0.052 (-2.595) ***	--	--	-0.124 (-2.079) ***	-0.118 (-3.184) ***
C_{10}	--	0.928 (4.152) ***	0.656 (4.418) ***	1.337 (4.952) ***	1.517 (7.382) ***
C_{11}	0.171 (2.248) ***	0.187 (1.717) ***	--	0.547 (4.919) ***	0.352 (3.917) ***
C_{12}	--	0.073 (2.196) ***	0.029 (1.927) *	--	--
C_{13}	0.019 (2.384) ***	0.029 (1.927) *	--	--	0.047 (2.834) ***
Adj-R^2	0.938	0.936	0.918	0.984	0.993
D.W	2.197	2.315	1.963	1.763	2.156

Table 4: Estimated results of output equation

	C_6		
C	5.616378 (8.749653) ***	5.824741 (7.724943) ***	5.094725 (8.014723) ***
C_1	-0.582305 (-0.702345)	--	--
C_2	--	-0.043582 (-0.932345)	--
C_3	--	-0.034853 (-1.134853)	--
C_4	--	--	-0.003485 (-2.1348543) ***
C_5	--	--	0.001345 (0.456123)
C_{14}	0.418329 (8.145821) ***	0.412386 (8.942365) ***	0.442734 (8.184123) ***
C_{15}	0.037964 (3.194823) ***	0.057312 (3.847193) ***	0.042761 (3.511093) ***
C_{16}	0.007482 (7.502954) ***	0.007941 (7.287164) ***	0.007348 (7.398163) ***
Adj-R^2	0.956874	0.998725	0.998742
D.W	2.647264	2.387421	2.174234

4. Conclusion

(1) China's industrialization process accelerates with the rapid development of the economy, which exacerbates the environmental pollution problems. The emissions of "three wastes" show an upward tendency year by year. On the whole, it is not optimistic about the current situation in China.

(2) This paper builds a joint model containing pollution equations and output equations used to study the relationship between chemical pollution and regional economic development. The regression results from the chemical pollution equation show that the chemical pollution has a linear relation with the regional economic development. A significance test at the 1% significance level also passes. The regression results from the output equation show that various chemical pollution indicators have a significantly negative impact on regional economic development, which suggests that economic growth will be stunted as the chemical pollution emissions increase; in addition, physical capital stock, human capital stock, and labor inputs play a significantly positive impact on regional economic growth, showing that these three can effectively drive the development of regional economy.

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