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ENVIRONMENTAL QUALITY AND ECONOMIC SUSTAINABLE DEVELOPMENT IN HENAN PROVINCE

Purpose. *Based on the econometric model (Kuznets curve) of the relationship between economic growth and environmental pollution – Environmental Kuznets Curve, this article analyses the relationship between economic growth and environmental pollution in Henan Province, and studies the natural economic relationship.*

Methodology / approach. *Three kinds of regional pollution index data of waste gas pollution and solid waste pollution and relative data of per capita GDP in Henan province were analyzed by using STATA software and OLS method was used to fit the relationship between environmental quality and economic growth, and the regression curve with the best fitting degree was obtained.*

Results. *This article analyses the relationship between the overall environmental quality and economic growth in Henan Province over the years. According to the established data model it is obviously that economic growth itself cannot promote the improvement of environmental quality. To realize the double goals of economic growth and environmental protection, the key is to find out the inherent law of economic change in the process of economic growth, so as to construct a long-term mechanism of promoting environmental friendly economic growth. It is necessary: strengthening of pollution control and reduce pollutant discharge; follow the economic road of recycling resources; optimizing industrial structure and promoting coordinated sustainable development; adhere to the policy of energy saving and emission reduction.*

Originality / scientific novelty. *Author's developed econometric model is very useful in empirical assessment for the sustainable development of resources, environment and economy in Henan Province, and to provide a decision-making reference for the development of ecological environment in Henan Province. Accordingly, the proposed method, in the face of high-speed economic development today, put forward the countermeasures of economic sustainable development.*

Practical value / implications*. Using the author's proposed method leads to the achievement of the following results: can better promote Henan Province economy and ecological environment coordinated development.*

Key words: *sustainable development, Environmental Kuztets curve, economic growth; environmental pollution, Henan province, China.*

Introduction and review of literature. With the progress of science and technology, great improvement of social productivity, humanity has created unprecedented material wealth. But with the rapid increase in population, excessive consumption of resources, environmental pollution, unemployment, ecological destruction and other issues are increasingly prominent, at the same time with the rapid development of the economy, the contradiction between economic development

and social development has gradually emerged. In the process of economic development, we can reduce the damage to ecological environment as far as possible, improve the ecological environment, and seek the coordinated development of economic development and ecological environment [1; 2; 3; 4]. Many scientists [5; 6; 7; 8; 9; 10] concern about confrontations in trilemma: population growth, economic growth and environmental sustainability – and reveals the vast incompatibility of current models of economic development with environmental sustainability. Using statistical data collected from across the globe, national economies and natural resource use were closely examined by an international team of scientists using a mathematical model [11; 12; 13; 14; 15; 16]. Thus, it is crucial to understand how to promote sustainability, i.e., reducing the environmental externalities without compromising economic growth.

Environment and people's life have a great relationship; the quality of the environment does not affect human production and life all the time. Muradian, O'connor and Martinez-Alie [12] define «environmental pressure» as the amount of pollutants emitted annually to reflect the extent of environmental degradation. Under the background of economic globalization and China's continuous improvement of market economy, Henan Province has entered to the rapid development stage of urbanization at present. Urbanization and environmental quality affect each other and restrict each other. With the rapid development of urbanization in Henan province, a series of environmental problems have been raised, and some problems have become obstacles to the sustainable development of cities. Economic growth depends on environmental development; there is a two-way relationship between economic growth and environmental quality change. The suitable environment is beneficial to the adjustment and development of the industrial structure, but the unreasonable economic structure or the incomplete development of the economy will affect the local and regional environmental quality problems and leave hidden trouble for the development of society and the reproduction of human beings. For conducting our research, we selected next parameters: gross national product (GDP), index of economic growth in Henan Province and also industrial waste gas, water waste and sulfur dioxide emissions in Henan Province.

The purpose of the article. The main objective of this article is to analyze the problems existing in the process of harmonious development of nature and economy, to make an empirical assessment for the sustainable development of resources, environment and economy in Henan Province, and to provide a decision-making reference for the development of ecological environment in Henan Province. Based on the econometric model of the relationship between economic growth and environmental pollution (based on Environmental Kuznets Curve), this article analyzes the relationship between economic growth and environmental pollution in Henan Province, and studies the natural economic relationship.

Results and discussion. This article analyzes the relationship between the overall environmental quality and economic growth in Henan Province over the years.

Economic development. Economic system of China had a lot transformation, from a single public ownership economy to an economy with multiple economic components coexisting with public ownership as the main body; from a planned economy to an economy supplemented by market regulation. Economic development and transformation are constantly promoting the process of social development. In recent years, the theme of modern development, such as realizing a well-off society in an all-round way, speeding up the transformation of economic structure, promoting scientific and technological innovation, economic environmental protection, building a harmonious society, «Belt and Road Initiative» and so on, has become more relevant actual themes.

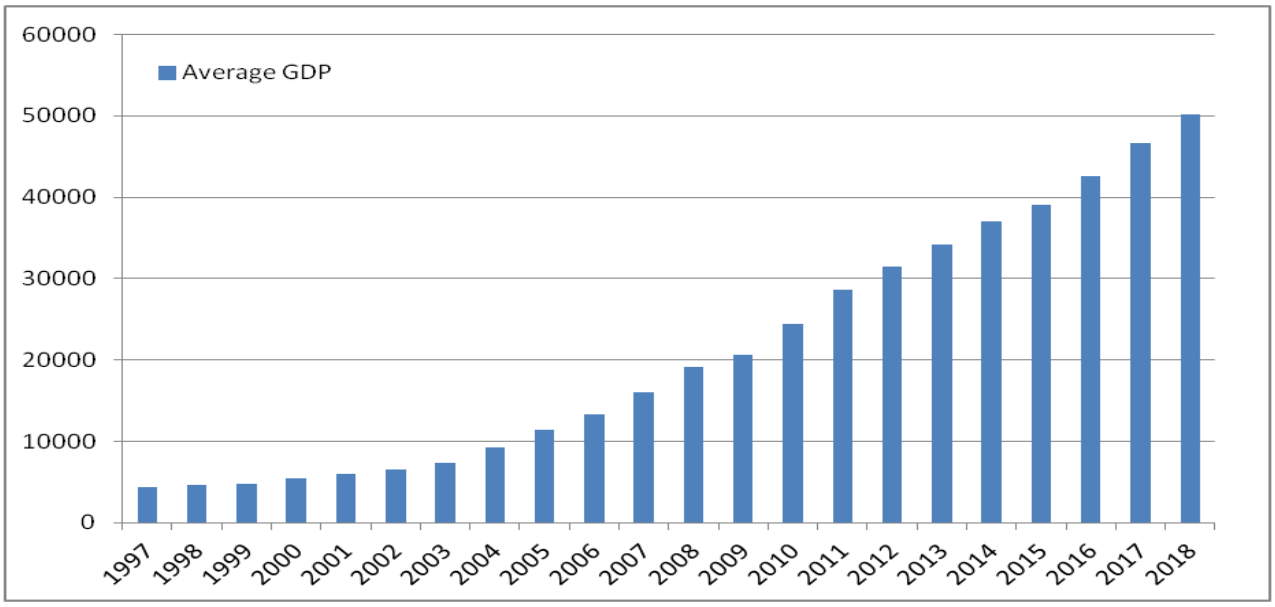

Fig. 1. GDP per capita in Henan Province, 1997–2018 (Unit: CNY)

Source: National Bureau of Statistics of the people's Republic of China.

With the continuous advancement of industrialization, urbanization, and informatization and high-quality development requirements, the profits of industrial enterprises in Henan Province, and the operating income of the Internet and related service industries have become more and more obvious. The GDP of Henan Province was 404.019 billion Yuan in 1997 to 480.558 billion Yuan in 2018, The average annual growth rate is 7.6 %. GDP per capita of Henan Province increased from 4,389.00 Yuan in 1997 to 50,152 Yuan in 2018, an average annual increase of 12.8 %. At the same time as the people's income continues to increase, the requirements for living standards and quality of life are also increasing.

Environmental Quality. In the past two decades, China has developed a lot of acts on environmental quality. After the 1992 United Nations Conference on Environment and Development, there was proposed to follow the scientific concept of development and to develop in an all-round, sustainable and coordinated manner. At the 17th National Congress, was put forward the establishment of ecological civilization, and the 18th Congress strengthened the promotion of ecological civilization. In the 20th century, was also discussed the development of circular economy and the construction of a resource-saving and environment-friendly society.

It can be said that a large part of the sources of these ideas and the problems of resources, environment and ecology was caused by the industrial revolution. With the continuous development of the economy, people's living standards are gradually improved and resources appear at the same time. All kinds of environmental pollution and ecological destruction problems, such as resources' shortage, environmental pollution and so on, are caused by the industrial revolution and unreasonable activities of humanity beings in the final analysis.

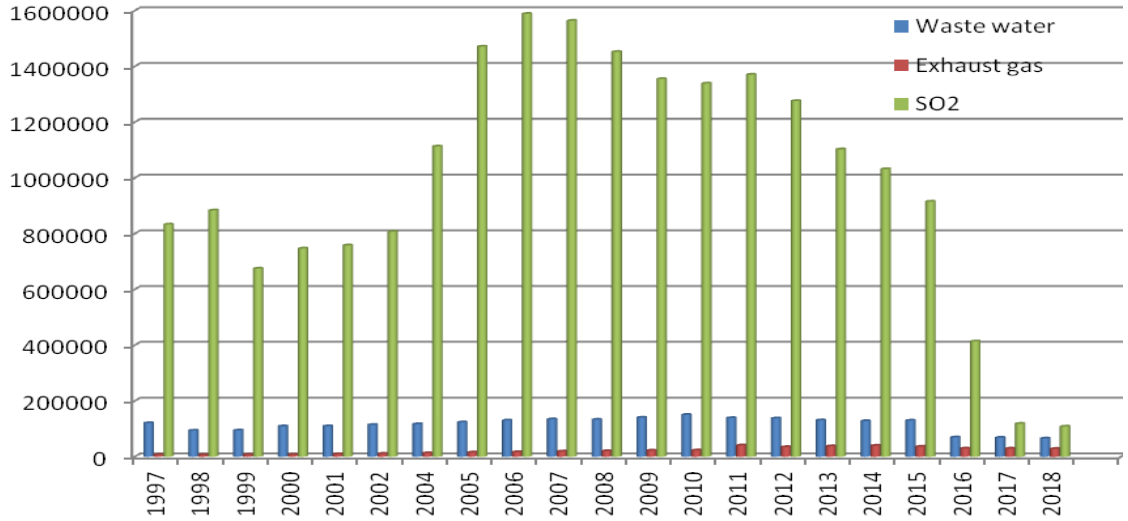

Fig. 2. Per capita GDP and Environmental Quality Indexes in Henan Province, 1997–2018 (Unit: CNY)

Source: National Bureau of Statistics of the people's Republic of China.

The rapid development of industry in Henan Province also poses a great challenge to the environmental quality of Henan Province. The total amount of industrial waste water in 1997–2018 was from 1.208 billion tons to 656.83 million tons in 2018. In these 20 years, the total amount of industrial waste water was from 1.208 billion tons to 656.83 million tons in 2018. As can be seen from the figures, industrial waste water has decreased somewhat in the past two decades, from seven hundred and ten billion one hundred and thirty nine million nine hundred and ninety nine thousand nine hundred and ninety nine m^3 in 1997–2018 to two trillion eight hundred and thirty two billion one hundred and forty five million m^3 in 2018, with an average annual growth rate of 23.8 %; From 1997 to 2018, sulfur dioxide increased from 833000.00 tons to 108212.56 tons, a drop in numbers, but China environmental problems are still a huge task. Although investment in industrial pollution control is increased every year and measures are implemented to improve the situation, the problem of environmental pollution is still serious in some areas.

In general, the relationship between economic development, water pollution and atmospheric environment has passed through the period of scale deterioration with rapid economic growth, and has entered the structural period of economic development and relatively stable environment, and is approaching the elimination period. Our tasks in this article were: to study the relationship between environmental quality and economic growth, to explore the path of harmonious development

between important links and economy, and to study the relationship between environmental quality and economic growth.

The environmental quality index must be the index which can reflect the environmental quality. In this article were selected the industrial waste water, waste of gas and sulfur dioxide emissions for evaluation of environmental quality. The index of economic development (per capita GDP of Henan Province) and industrial waste water parameters were collected from the national data network of the «National Bureau of Statistics of the people's Republic of China». The data of industrial waste gas and industrial sulfur dioxide (SO_2) were selected from the following tables: the Environmental situation Bulletin of Henan Province over the years and the Statistical Yearbook of Henan Province. With the help of STATA software, the environmental quality index is taken as dependent variable and the per capita GDP as independent variable for curve fitting simulation.

Table 1

Per capita GDP and Environmental Quality Indexes in Henan Province from 1997 to 2018

Year	GDP per capita, CNY	WW, ten thousand tons	EG, billion m^3	SO_2, tons
1997	4389.00	120800.00	7101.40	833000.00
1998	4643.00	93700.00	6618.92	883600.00
1999	4832.00	94544.00	6910.50	675000.00
2000	5449.73	109200.00	7436.00	747000.00
2001	5959.08	109600.00	9239.00	758000.00
2002	6486.97	114400.00	10644.00	807300.00
2003	7375.90	114200.00	11991.60	901700.00
2004	9200.59	117000.00	13103.00	1113000.00
2005	11346.50	123500.00	15498.00	1471100.00
2006	13279.00	130200.00	16770.00	1588800.00
2007	16012.00	134300.00	18890.00	1563900.41
2008	19181.00	133100.00	20264.09	1452000.00
2009	20597.00	140300.00	22185.00	1355000.51
2010	24446.00	150400.00	22709.00	1338701.00
2011	28661.00	138800.00	40805.34	1370504.08
2012	31499.00	137400.00	35006.34	1275909.33
2013	34211.49	130800.00	37669.53	1102700.00
2014	37071.72	128000.00	39635.41	1031700.00
2015	39122.61	129800.00	36285.61	915000.00
2016	42575.00	69500.00	29810.21	413622.67
2017	46674.00	68630.00	29439.65	118338.49
2018	50152.00	65683.00	28321.45	108212.56

Source: National Bureau of Statistics of the people's Republic of China.

The fitting data adopts the best fitting effect and the simplest four-order polynomial, and the expression is as follows:

$$Yt = \beta_0 + \beta_1 X_t + \beta_2 X_t^2 + \beta_3 X_t^3 + \beta_4 X_t^4,$$

where Y – is pollutant emission;

X – is per capita GDP;

t – is time;

β_0, β_1, β_2, β_3, β_4 – are model parameters.

As can be seen from the above formula, different combinations of parameters should have different curve forms (Table 2).

Table 2

The Curve form corresponding to the combination of different parameters in the Model

β	Curve form
$\beta_1 > 0$, $\beta_2 = \beta_3 = \beta_4 = 0$	Linear monotone increment
$\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 = \beta_4 = 0$	"U"
$\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 > 0$	"N"
$\beta_1 < 0$, $\beta_2 = \beta 3 = \beta 4 = 0$	Linear monotone decline
$\beta_1 < 0$, $\beta_2 < 0$, $\beta_3 = \beta_4 = 0$	"U"
$\beta_1 < 0$, $\beta_2 > 0$, $\beta_3 < 0$	"N"

Source: calculated by authors.

Four-curve regression analysis of industrial waste water, waste gas, sulfur dioxide and per capita GDP in environmental quality index was carried out.

The fitting Curve Analysis of the relationship between Industrial Waste water discharge and per capita GDP. The resulting curve of the relationship between industrial waste water discharge and per capita GDP is shown in the first diagram of Table 3. The horizontal axis of the diagram is GDP; the vertical axis is the discharge of industrial waste water. According to Table 3, R^2 of industrial waste water is 0.83, t value is 8.40 and -9.27. We know that when t > 2, the level of significance is higher. However, the two simulation values of industrial waste water are relatively large, the significance level is more obvious.

Table 3

Regression results of GDP and Waste water

```
. reg y1 x x2

      Source |       SS       df       MS              Number of obs =      22
-------------+------------------------------           F(  2,    19) =   46.58
       Model |  1.0136e+10     2  5.0679e+09           Prob > F      =  0.0000
    Residual |  2.0670e+09    19   108790698           R-squared     =  0.8306
-------------+------------------------------           Adj R-squared =  0.8128
       Total |  1.2203e+10    21   581086694           Root MSE      =   10430

------------------------------------------------------------------------------
          y1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           x |    5.453153   .6492295     8.40   0.000       4.0943    6.812006
          x2 |   -.0001185   .0000128    -9.27   0.000    -.0001452   -.0000917
       _cons |     80196.2   6139.349    13.06   0.000     67346.39       93046
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Source: calculated by authors.

Table 4

Regression results of GDP and exhaust gas

```
. reg y2 x3 x4

      Source |       SS       df       MS              Number of obs =      22
-------------+------------------------------           F(  2,    19) =   72.63
       Model |  2.5450e+09     2  1.2725e+09           Prob > F      =  0.0000
    Residual |   332868325    19  17519385.5           R-squared     =  0.8843
-------------+------------------------------           Adj R-squared =  0.8722
       Total |  2.8779e+09    21   137041708           Root MSE      =  4185.6

------------------------------------------------------------------------------
          y2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          x3 |    1.85e-09   1.88e-10     9.82   0.000     1.45e-09    2.24e-09
          x4 |   -3.49e-14   3.97e-15    -8.81   0.000    -4.32e-14   -2.66e-14
       _cons |    10556.56    1255.67     8.41   0.000     7928.408    13184.7
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Source: calculated by authors.

Table 5

Regression results of GDP and SO_2

```
. reg y3 x x2

      Source |       SS       df       MS              Number of obs =      20
-------------+------------------------------           F(  2,    17) =   51.53
       Model |  1.8106e+12     2  9.0529e+11           Prob > F      =  0.0000
    Residual |  2.9868e+11    17  1.7569e+10           R-squared     =  0.8584
-------------+------------------------------           Adj R-squared =  0.8417
       Total |  2.1093e+12    19  1.1101e+11           Root MSE      =  1.3e+05

------------------------------------------------------------------------------
          y3 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           x |    109.3443   10.86767    10.06   0.000     86.41554    132.2731
          x2 |   -.002482   .0002453   -10.12   0.000    -.0029996   -.0019644
       _cons |    313466.6   88938.24     3.52   0.003     125823.3    501109.8
------------------------------------------------------------------------------
```

Source: calculated by authors.

At the same time, we can see the curve of the relationship between industrial waste water discharge and per capita GDP (Fig. 4). The trajectory is that the growth first reaches a peak and then decreases, and the highest point is about the highest point. GDP appeared at about 2500 Yuan, possibly related to the policy and recent economic situation. From the graph point of view, it is beneficial to control and improve the industrial waste water and reduce the discharge of industrial waste water by increasing the investment of the industrial pollution prevention and control fund,

and carrying on the treatment and examination to the enterprises with serious pollution.

Table 6

Regression results of Economic growth and Environmental Quality Model in Henan Province

Model Parameter				Model Testing			
Index	Parameter	Number	t	Signif t	F	Signif F	R^2
Waste Water	β_1	5.453153	8.40	0.000	46.58	0.0000	0.830
	β_2	-0.0001185	-9.27	0.000			
Exhaust Gas	β_3	1.85e-09	9.82	0.000	72.63	0.0000	0.8843
	β_4	-3.49e-14	-8.81	0.000			
SO_2	β_1	94.3419	10.10	0.000	75.12	0.0000	0.8877
	β_2	-0.0021006	-11.43	0.000			

Source: calculated by authors.

The fitting Curve Analysis of the relationship between Industrial Exhaust Gas Emission and per capita GDP. The resulting curve of the relationship between industrial exhaust emissions and per capita GDP is shown in the next diagram (Fig. 5) of Table 4. The horizontal axis of the diagram is GDP, the vertical axis – is the industrial exhaust emissions. It can be seen from Table 4 that R^2 of industrial exhaust gas is 0.8843 and t value is very high, indicating that there is an extreme dominant correlation. Significant indicates that the industrial exhaust emissions of Henan Province are significantly higher than those of Henan Province at a significant level of 1/1000. At the same time, we can see from the relationship between industrial exhaust gas emissions and per capita GDP (Fig. 5) that its trajectory is that the growth first reaches a peak and then decreases, with the highest trend. Dot appears in GDP for about 2500 Yuan. Compared with the curve of industrial waste water, the curve of industrial waste gas increases slowly, but the trend is obvious.

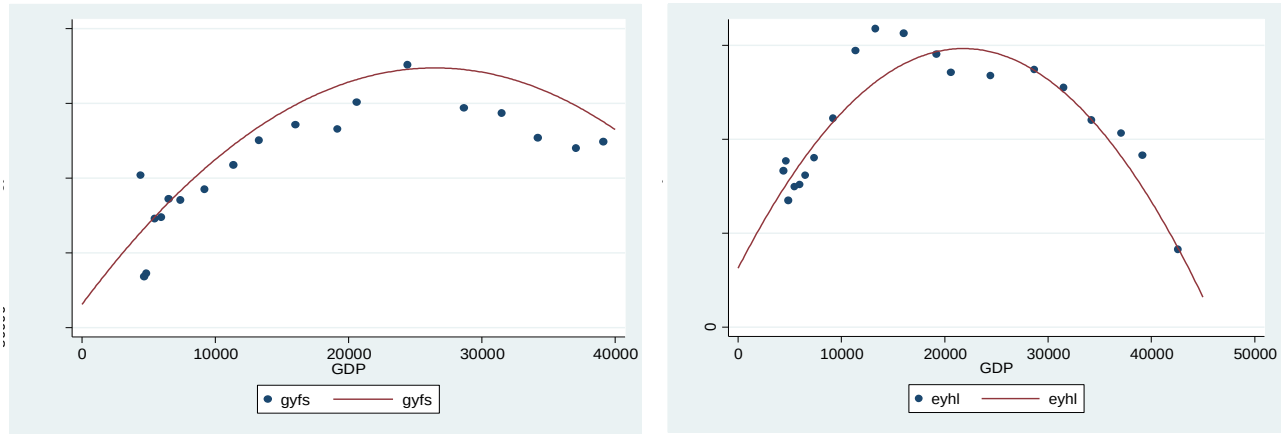

Fig. 4–5. Waste water, waste gas emissions per capita GDP curve regression analysis

Source: calculated by authors.

The fitting Curve Analysis of the relationship between Industrial sulfur dioxide Emission and per capita GDP. The resulting curve of the relationship

between industrial SO_2 emissions and per capita GDP is shown in Table 5 (Fig. 6). The horizontal axis of the diagram is GDP, the vertical axis – industrial sulfur dioxide emissions. As can be seen from Table 5, R^2 of industrial sulfur dioxide is 0.8877, t value is 10.1 and – 11.43, respectively. Significance indicates that the industrial sulfur dioxide emissions in Henan Province are still significantly higher than those in Henan Province at a significant level of 1/1000. At the same time, from the relationship between industrial exhaust gas emissions and per capita GDP, we can see that its trajectory is inverted "U" type, and the radians are quite significant. In 1997, the highest point was concentrated between 1500 and 3000 Yuan GDP, especially in comparison with the first two graphs.

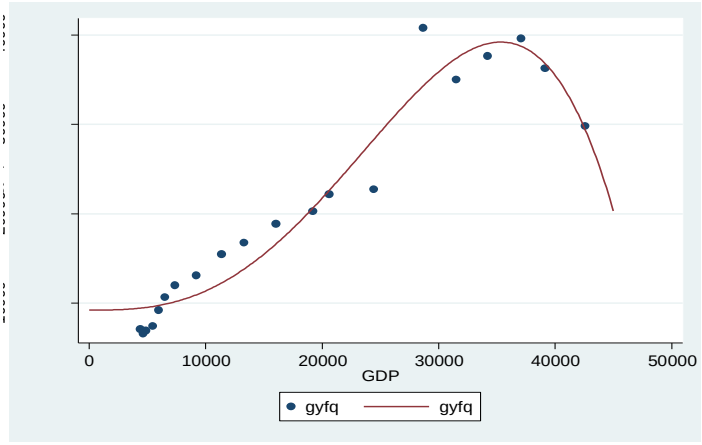

Fig. 6. SO_2 emissions per capita GDP curve regression analysis

Source: calculated by authors.

Through the established data model were confirmed that there is no inherent specific trend between economic growth and pollution emissions. Only when the effects of other potential factors are taken into account, the relationship between them takes on a different form, which means that economic growth itself cannot promote the improvement of environmental quality. From another point of view, it also reflects that implementing pollution reduction policies and increasing the cost of environmental pollution control will not hinder economic growth. To realize the double goals of economic growth and environmental protection, the key is to find out the inherent law of economic change in the process of economic growth, so as to construct a long-term mechanism of promoting environmental friendly economic growth. The development of industry in the economy will improve people's economic level, but at the same time, it also brings some problems, such as the continuous pollution of the environment and the decline of the quality of the environment that people depend on for their lives, and so on.

Conclusions. ***Strengthen pollution Control and reduce Pollutant discharge.*** The impact of industrial pollution on the environment cannot be underestimated. Only by continuously increasing the intensity of pollution control can the economic development and the good development of environmental quality be guaranteed. Although the environmental quality of Henan Province has been greatly improved in recent years, but the average emissions in the last two decades still account for a large

proportion. The average emission is still very significant, so Henan Province can introduce more advanced equipment, reduce industrial waste water and exhaust gas emission, filter it, increase the monitoring of industrial life, and create a better living environment for people. At the same time, recycle wastes and reduce them to achieve environmental protection.

Follow the Economic Road of Recycling, Recycling Resources. It necessary to adjust the economic structure; to improve the effective use of resources; to speed up the establishment of eco-park; to optimize the recycling industry. Some pollutants discharged from life and industry also have utilization value. Reuse and recycling of wastes and other substances produced in industry can reduce not only the cost of production but also the discharge of harmful substances.

Optimizing Industrial structure and promoting coordinated Sustainable Development. It is necessary to promote the development of the tertiary industry in Henan Province, to make use of the special tourism resources in Henan Province, to make great efforts in the service industry, to strengthen the supervision of industry and to pay attention to the development of agriculture at the same time. It is also needed to coordinate the relationship and good development between the primary industry, the secondary industry and the tertiary industry.

Adhere to the policy of energy saving and emission reduction to improve public awareness of energy saving and emission reduction. It is necessary implement energy saving and emission reduction policies, improve energy use with involving new energy recourses, and reduce pollution emissions. For people recommended do not drive the private car, commutes to and from work by bus. It should to start with little things, in life in order to achieve the economic and environmental win-win in Henan Province contribute a little strength.

In the study of the relationship between environmental quality and economic growth in Henan Province, by fitting and analyzing the typical data of environmental quality and per capita GDP, we can see that the economic level of Henan Province is constantly improving. Although there is a trend towards better environmental quality than before, but emissions are still large. It shows that there are still some deficiencies in the industrial control and investment in Henan Province. Government departments should strengthen the supervision of industrial enterprises, citizens should improve their awareness of emission reduction and habits, optimize the industrial structure, increase the intensity of pollution control to follow the economic road of circular development.

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