Empirical research on the correlation between economic development and environmental pollution in natural resource abundant regions: the case of China Shaanxi province

Bo Luo \(^1\) and Jinsuo Zhang \(^{2,3}\)

\(^1\) School of Safety Science and Engineering, Xi'an University of Science and Technology, No.58 Yanta Road, Xi'an, Shaanxi Province, P.R. China;
\(^2\) College of Economics and Management, Yan'an University, No. 580 Shengdi Road, Yan'an, Shaanxi Province, P.R. China.
\(^3\) Mark56zhang@163.com

Abstract. This paper investigates the relationship between economic development and environmental pollution in natural resource abundant regions via testing the Environmental Kuznets Curve (EKC) hypothesis by regression analysis, based on the statistical data of per capita GDP growth and environmental pollution indicators in Shaanxi Province from 1989 to 2015. The results show that the per capita GDP and environmental pollution in Shaanxi Province do not always accord with the "inverted U" Environmental Kuznets Curve, which mainly show "N" shapes; only SO\(_2\) show the "Inverted U" shapes.

1. Introduction

Natural resource abundant regions provide reliable support for resource development as well as energy supply in China. However, the environmental problems arisen from the imbalance of industrial structure are more prominent, which deserves special attention. The analysis of the relationship between economic growth and environmental pollution in natural resource abundant regions have an significant influence on the way of resource-saving and environment-friendly development of China.

As a demonstrating example, the distribution of mineral resources in Shaanxi Province is obvious. Northern Shaanxi and Weihe are rich in high quality coal, oil, natural gas, cement limestone, clay and salt minerals. Guanzhong is mainly rich in gold, molybdenum, building materials and underground hot water and mineral water. Southern Shaanxi is rich in black metal, nonferrous metals, precious metals and various types of non-metallic mineral. Shaanxi has identified the potential value of mineral resources reserves of 42 trillion Yuan, accounting for about one-third of the country, and ranking first in China. Shaanxi's economic development has been accelerated for the construction of energy and chemical bases in northern Shaanxi since 1998 and the rapid development of energy extraction and processing, but the environmental pollution has become more and more serious. The pollution of industrial "three wastes" has become a key factor affecting the regional ecological environment deterioration. Therefore, it is of great significance to analyze the relationship between the "three wastes" emission and the economic development in Shaanxi Province, to find the causes in addition to put forward countermeasures for green develop in the region.

The economist S. Kuznets (1995)[1] puts forward the Kuznets curve to predict the relationship between economic development and income gap.
That is the income gap will increase with the increase in per capita income, but to a certain extent, this gap will shrink. In the same period, Grossman and Krueger (1991)[2] started to research the relationship between environmental quality and per capita income. World Bank (1992), Shafik and Bandyopadhyay (1994), Holtz-Eakin and Selden (1995)[3] then followed the research. Panayotou (1996)[4] called this inverted U-shaped relationship as Environmental Kuznets Curve (EKC), which means that environmental quality begins to decline with the increase in income, and improve after a certain inflection point.

Research on the relationship between economic growth and environmental pollution started around 2000 in China (Zhang Xiao, 1999; Shen Manhong, 2000)[5,6]. Most studies support this hypothesis, but some not. Chen Huawen et al. (2004)[7] have investigated the multi-index environment Kuznets curve hypothesis and found that different environmental quality indicators corresponded to different turning points and policy response helped to improve the environmental quality.

Shao Fengxiang et al. (2012)[8] verified the Kuznets curve of carbon emission in Shaanxi Province and found its key influencing factors. But Zhao Xikang (2005) [9] found that most of China's pollutant emissions do not have a typical EKC characteristics, the environmental pollution has no obvious turning point, and government environmental protection can improve the ECK shape. Zhang Jinsuo et al. (2017) [10] found that environmental pollution in northern Shaanxi is becoming more and more serious for energy economic development.

Today the development of metropolis and modern cities is based on the achievement of certain conditions of quality of life. Indoor and outdoor air quality assessments are therefore the essential parameters for project of plant to achieve optimum environmental conditions [11-13]. Many scholars have expanded the research of the relationship between environmental quality and per capita GDP.

Zhang Jinsuo (2009)[14] first proposed the EKC analysis between industrial GDP and environmental pollution indicators, then Wang Xilian (2009) [15] used the system dynamics to study the environmental development trend of Shaanxi.

Wei Yiming et al. (2014) [16] conducted an empirical study of EKC through per capita energy consumption and per capita electricity consumption in China. Sun Weizeng et al. (2014) [17] used EKC to validate the incentive role of energy and environmental indicators in environmental assessment, official promotion and local environmental improvement.

Environmental pollution assessments, carried out with new techniques and systems and modern generation sensors, can be of great help for environmental monitoring of urban centers to control for the threshold values of the most important environmental parameters [18, 19].

As mentioned above, the relationship between economic growth and environmental pollution are different in each stages of development, its shape is not uniform; Government environmental policy can help improve the environmental quality under economic growth, affect the EKC curve development trend, appear of the inflection point time.

Based on the previous studies, this paper takes Shaanxi Province as an example. The rest of the article is structured as follows. Section 2 introduces the stage of industrial development and its pollution in Shaanxi; Section 3 introduces the data, methodology and presents the empirical results; Section 4 discussion; and Section 5 concludes the study.

2. An analysis of Shaanxi's economic development

2.1. Industrial stage of Shaanxi Province

The 2016 Shaanxi Provincial Statistical Bulletin shows that annual GDP of Shaanxi is 1916.539 billion Yuan, including primary industry 1693.84 billion Yuan, the secondary industry 9390.88 billion Yuan and the tertiary industry 808.067 billion Yuan, an increase of 7.6% over the previous year. The structure from 8.8: 51.5: 39.7 in 2015 become 8.8: 49.0: 42.2 in 2016. Per capita GDP of Shaanxi reached 50395 Yuan, which higher than the national average and ranking 13th in China. (1) Shaanxi Province is in the primary stage of post-industrialization based on Chenery Model from the per capita
GDP index. Per capita GDP of Shaanxi Province in 2016 is 50395 Yuan, about 7587 US dollars according to the average exchange rate of 2016, and 14373.93 US dollars according to the 2011 dollar purchasing power parity, which in the primary stage of post-industrialization based on Chenery Model.

(2) Shaanxi Province is in the later stage of industrialization judged from the industrial structure. According to the three industries data of Shaanxi Province in 2016, the proportion of the primary industry is less than 10%, and the secondary industry decreased rapidly from 51.5% to 49.0% in 2015 but still higher than 42.2% of the tertiary industry. Shaanxi Province is currently in the later stage of industrialization from the industrial structure. (3) Shaanxi Province is in the middle of industrialization judged by proportion of employment in the primary industry. The 2015 proportion of employment in primary industry of Shaanxi Province accounted for 38.09%, which is in the mid-industrial range of 30% -45%. (4) Shaanxi is in the middle stage of industrialization based on the urbanization rate. In 2016, the urbanization rate of Shaanxi was 55.34%, which was lower than the national average of 57.35%, but still in the range of 50% -60%, in the middle of industrialization. It can be seen that Shaanxi Province is in the post-industrialization stage based on per capita GDP, in the later stage of industrialization based on the tertiary structure, in the middle stage of industrialization based on the employment structure and urbanization level, but purchasing power parity per capita GDP overestimates the level of economic development, Urbanization lagged behind the industrial and urbanization that underestimate the stage of the industrialization development [20]. So we conclude that the industrialization of Shaanxi Province is in the medium-term stage and continue to convert to the later stage of industrialization.

Table 1 gives the basis for judging the development of industrialization in Shaanxi Province.

| Index                              | Data of Shaanxi | Stage of Industrialization |
|------------------------------------|-----------------|---------------------------|
| Per capita GDP ($)                 | 7587            | Post-industrialization    |
| Industrial structure(%)            | 8.8; 49.0; 42.2 | Later stage of Industrialization |
| The secondary industry to GDP (%)  | 49.00%          |                           |
| Proportion of employment in primary industry (%) | 38.09%          | Middle stage of industrialization |
| Urbanization rate (%)              | 55.34%          | Middle stage of industrialization |
| Comprehensive identification       |                 |                           |

Source: "Statistical Communiqué of National Economic and Social Development of Shaanxi Province in 2016" and "Shaanxi Statistical Yearbook 2016".

2.2. Economic growth and environmental pollution in Shaanxi Province

The rich mineral resources led to rapid development of industry in Shaanxi Province. The GDP of the region increased from 35.84 billion Yuan in 1989 to 1 802.19 billion Yuan in 2015, with an average annual growth rate of 16.26%; per capita GDP from 1 124 Yuan in 1989 to 47 626 Yuan in 2015, with an average annual growth rate of 15.50%; At the same time, the proportion of secondary industry in the region has changed significantly, from 44.22% in 1989 to 51.5% in 2015 and decrease to 49.0% in 2016. Economic growth is affected by fluctuations in the energy sector, with a typical economic development characteristic of natural resource abundant regions.

However, the environmental problem caused by the industrial "three wastes" in Shaanxi Province has become increasingly worse for the development of industry, especially after the Weibei energy extraction and the construction of the energy and chemical base in northern Shaanxi.

The output of industrial waste gas was 17303.4953 billion cubic meter in 2015, which was 9.94 times of 1740.82 billion cubic meter in 1989(see Figure 1).
Figure 1. Total volume of industrial waste gas emission (100 million cu.m) of Shaanxi in 1989-2015 based on: Shaanxi Statistical Yearbook 1990-2016.

Figure 2. Volume of industrial solid wastes produced (10 000 tons) of Shaanxi in 1989-2015 based on: Shaanxi Statistical Yearbook 1990-2016.

Industrial solid wastes production was increased rapidly, which declined in 1999 and 2009, accord with two financial crises coincides. But the overall trend maintain sustained upward, the amount of production reached 93.30 million tons in 2015, is 6.17 times bigger than 1989(see Figures 2).

Figure 3. Volume of industrial sulphur dioxide emission (10 000 tons) of Shaanxi in 1989-2015 based on: Shaanxi Statistical Yearbook 1990-2016.
SO₂ emissions continue to fluctuate accompany with economic fluctuations. The number in 2015 is smaller than 0.616 million tons in 1989 (see Figures 3).

**Figure 4.** Total volume of industrial waste water discharged (100 million tons) of Shaanxi in 1989-2015 based on: Shaanxi Statistical Yearbook 1990-2016.

Industrial waste water discharged 414 million tons in 1989 fell to 377.3 million tons in 2015 and accompany fluctuate with economic fluctuations. Due to the situation of water shortage in Northwest China, it can’t get much bigger (see Figures 4).

To sum up, the Figures.1-4 show that the industrial "three wastes" pollution emissions in Shaanxi Province change with the economic changes, volume of industrial waste gas and industrial solid wastes are on the rise, volume of SO₂ and industrial waste water emissions are fluctuate with the economic fluctuations.

3. An empirical analysis of EKC: case of Shaanxi Province

3.1. Related indicators and data
In the previous EKC empirical study, pollution concentration, pollutant emissions and resource extraction are often used as environmental variables. In this article, we select per capita GDP and environmental pollution indicators include: Total Volume of Industrial Waste Gas Emission, Volume of Industrial Solid Wastes Produced, Total Volume of Industrial Waste Water Discharged and Volume of Industrial SO₂ Emission based on the characteristics of coal and oil exploitation in the area and the availability of data. The data source is Shaanxi Statistical Yearbook during the period from 1990 to 2016.

3.2. Correlation analysis
According to Table 2, Industrial Waste Gas Emission and Industrial Solid Wastes Produced are significantly correlated with the per capita GDP at the level of 0.001, Industrial SO₂ Emission and per capita GDP correlated at the level of 0.05, Industrial Waste Water Discharged and per capita GDP is not significantly correlated (see Figures 5).

**Table 2.** Correlation analysis of per capita GDP and environmental indicators in Shaanxi.

| Indicators           | Industrial Waste Gas | Industrial Solid Wastes | Industrial SO₂ | Industrial Waste Water |
|----------------------|----------------------|-------------------------|----------------|------------------------|
| R                    | 0.987**              | 0.962**                 | 0.445*         | 0.157                  |
| P                    | 0.000                | 0.000                   | 0.020          | 0.434                  |

Note: R is the correlation coefficient, P is the associated probability value, ** means significantly correlated at the level of 0.10 (bilateral), * means significant correlation at the level of 0.05 (bilateral).
3.3. Model

First, draw scatter plot through the indicators of Industrial Waste Gas, Industrial Solid Wastes, Industrial SO$_2$ and Industrial Waste Water with per capita GDP respectively to explore their potential correlation (see Figures 5a, 5b, 5c and 5d).

We find that Industrial Waste Water, Industrial Solid Wastes is linear correlation with per capita GDP, Industrial SO$_2$, Industrial Waste Water is not linear correlation with per capita GDP.

![Figure 5a](image-url-a)  
![Figure 5b](image-url-b)  
![Figure 5c](image-url-c)  
![Figure 5d](image-url-d)

**Figure 5.** Scatter plot of environmental indicators with per capital GDP.

Then, use EKC basic function types include quadratic function, cubic function, exponential function, logarithmic function and composite function to estimate the regression curve by SPSS software.

The results show that the cubic curve is best fitted. The results of the per capita GDP and environmental indicators in Shaanxi Province are shown in Table 3 through curve estimation by cubic function.
It can be seen from Table 3 that there is a significant correlation between industrial waste gas, industrial solid wastes with per capita GDP ($R^2$ is greater than 0.9, $P < 0.001$), which has a sufficient explanatory significance for EKC; Industrial SO$_2$ and per capita GDP have a general correlation ($R^2=0.663$, $P < 0.001$); Industrial waste water does not have a statistical significance.
3.4. Results and analysis
After the metrological model fitting, the function fitting curve of the "three wastes" emission with the per capita GDP of Shaanxi Province was obtained by SPSS (see Figures 6a, 6b and 6c).

It can be seen from Figure 6 that the fitting curve between per capita GDP and industrial waste gas in 1989-2000 is similar to the left part of "N" shapes and the upward trend is obvious; The per capita GDP and the industrial solid waste curve show the "N" shapes; Although the per capita GDP and industrial SO$_2$ fitting cubic function model, but the graph is similar to the "inverted U" shapes and the industrial SO$_2$ began to decrease gradually.

4. Discuss on the particularity of EKC in Shaanxi Province

4.1. Shaanxi Province is still in middle stage of industrialization
In recent years, the economy of Shaanxi Province has been growing rapidly, but still in the middle stage of industrialization, the economic growth mainly relies on resource-extraction industries like coal, oil. The industrial structure of natural resource abundant regions under the rapid development of economy means the slowdown of environmental quality recovery in Kuznets curve effect. That is why the economic development of Shaanxi Province shows great deterioration of the environment with rapid economic growth especially in the aspects of industrial waste gas and industrial solid wastes. The change of SO$_2$ and industrial waste water is matched with the change of energy economy in Shaanxi Province. At the same time, industrial waste water can’t be too large for lack of water resources in the northwest China.

4.2. Region distribution of environmental pollution is obvious
Shaanxi Province is divided into three regions, northern Shaanxi, Guanzhong and southern Shaanxi. The development mode of Northern Shaanxi is typically extensive development, its environmental pollution mainly from resource-extraction industries like coal, oil, coal chemical and petroleum processing. In 2014, the proportion of secondary industry in northern Shaanxi nearly 70%, but down to 62% in 2015 due to the global coal downturn and the national economic downturn, affected by industrial fluctuations, the economy of Shaanxi Province slowdown. In Guanzhong, the total amount of environmental pollution has increased and it’s number is larger, but the proportion of pollution has decreased for the proportion of secondary industry of Guanzhong in Shaanxi is biggest. In southern Shaanxi, there are few industries and the environmental quality is high.

5. Conclusions
This paper empirically investigated the EKC hypothesis in natural resource abundant regions, and therefore, the relationship between economy development and environmental pollution through the channels of per capital GDP and pollution emission in Shaanxi, which is an important destination region in Far East. The theoretical EKC framework has been taken into consideration in empirical analysis with this respect. The results of the present study are of interest to both scholars and policy makers due to the reason that Shaanxi is one of the most important provinces of China, where its economy is linked with diverse energy resources.

The justification for doing this research is that energy development is expected to be in a statistical relationship with environment pollution in such a extensive development of economy.

Results of the present study did not confirm the validity of EKC hypothesis through the channel of economy growth and environment pollution. Per capital GDP exerts positive effects on emissions in Industrial waste gas emission and industrial solid wastes produced and show the "N" shapes; Per capital GDP also has a positive impact on the level of industrial SO$_2$ emission in the short-term period and negative impact on the long-term period, which shows "inverted U" shape in the case of Shaanxi.

Results of this study suggest important implications for policy makers: the extensive development of industrial leads increases in industrial waste gas and industrial solid wastes in the case of Shaanxi.
and decline in industrial SO\textsubscript{2} on the long-term period, the EKC hypothesis through industrial development is partly confirmed.

This reveals that the environmental conservation policies are useful on industrial SO\textsubscript{2} emission and the industrial structure should be upgrade, in order to meet the turning point of industrial waste gas and industrial solid wastes. Therefore, results of this study suggest that while industry promotes economic growth in Shaanxi, not only the GDP but also the protection policies should be link with promotion of local officials.

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