Journal of Applied Sciences

ISSN 1812-5654

science alert

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Journal of Applied Sciences 14 (9): 918-924, 2014
ISSN 1812-5654 / DOI: 10.3923/jas.2014.918.924

A Study of the Relationship among Hubei's Population Growth, Environmental Quality and Economic Development

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Abstract: This study analyzes the relationship among Hubei's population growth, economic development and environmental quality. The results show that, in recent years, Hubei's population growth rate has gradually decreased, but large natural growth has promoted the expansion of economic scale to a certain extent. Economic development influenced the distribution of population and increased demand for resources, resulting in increased pollution emissions. Data shows that, with the economic development, Hubei's environmental quality was in the right part of the EKC curve, namely the change for the better. But exhaust emission displayed that industry had extensive development pattern. Therefore, measures should be taken to improve the contradiction between environment and economy.

Key words: Population growth, economic development, environmental quality

INTRODUCTION AND THEORETICAL BACKGROUND

With the progress of China's economic growth and industrialization, people have exploited more and more resources and industrial emissions are also increasing year by year. During the process of urbanization, the issue of population growth has also attracted more attention.

As for Hubei Province, in recent years, environmental conditions have been worsening, as the "province of thousand lakes", the lake water pollution levels. Hubei locates in Central China which is populous and resource-rich. Its economic development also plays a very important role in central China rise. Therefore, research on the relationships among environmental quality, population growth and economic development help to provide reference for the coordinated development of Hubei's population, economy, resources and environment.

As for the research on the relationship between economic growth and environmental pollution, the most representative is the U.S. economist Grossman and Krueger (1995) Environment Kuznets Curve (EKC) hypothesis. The hypothesis attempted to explain if there is no policy intervention, a country's overall level of environmental quality would first be deteriorated and then improved with economic growth. They used cross-country data to show the existence of EKC.

In the 1990s, a large number of scholars have carried out research on the EKC hypothesis; the main difference is the data and models. Some scholars have used panel data, such as Selden and Song (1994), Dinda (2004). Some researchers have used historical data, such as Sun (1999), he used historical data of the U.S. carbon dioxide emissions from1970 to 2000 to establish a model to verify the existence of the EKC. Some scholars have studied both panel data and historical data, such as (Galeotti *et al*., 2006).

As for the model, some researchers used the simplified model. The most commonly used models are $Y = a+bX+cX^2$ and $Y = a+bX+cX^2+dX^3$ which are about resources, environment and revenue. For example, Panayotou (1997) used the model $Y = a+bX+cX^2$ to prove the existence of EKC. Some researchers used logarithmic model to highlight model's features, such as Stern and Common (2001), he adopted $\Delta(E/Y) = a+b\Delta(\ln E/Y)+c\Delta(\ln E/Y)^2$ and got "U" shaped relationship between per capita income and environmental stress. Martinez-Zarzoso and Bengochea-Morancho (2004) adopted $Y = a+b \ln X+c(\ln X)^2+d(\ln X)^3$ and obtained "N" shaped relationship.

About the relationship between population growth and economic development, there were three main points. The pessimistic population theory considered that population, capital, food, non-renewable resources, environmental pollution were the major factors affected economic growth and they influenced each other and

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mutual restrained. The population optimistic economic theory suggested that in the long run, population growth will stimulate the generation and application of science and technology which would greatly promote the economic growth. The moderate human population theory analyzed the relationship between population growth and economic growth from dynamic point of view. They explained that population growth might bring both beneficial and adverse effects to economic growth.

In theoretical research, the majority of articles study from the environmental, economic, resource coordination development perspective, such as (Chen and Sun, 2006; Chen and Zeng, 2004; Wei, 2002). On the data analysis, most studies started from EKC model abroad, they used historical data, such as (Liu, 2005; Cai and Huang, 2006). Yao and Tang (2010) made correlation analysis on Guangxi's economic growth and environmental quality. Cai (2010) determined main factors influencing environmental quality regression analysis. Yu *et al.* (2013) analysis the relationships among economic growth, investment structure and the environment effect.

About the relationship between population growth and economic development, domestic scholars mainly researched from the following aspects: (1) On labor resources and economic growth, population and the change of economic structure, population and national income distribution, population and national economic growth, the relationship between population and resources environment, (2) On changes of population growth, structure changes and distribution and the overall socio-economic development process, put forward the necessity of population and economic coordinated development and (3) Combined with social differences in production methods, proposed the new concept of economic population, developed the optimal population, optimal population economic benefits and other new topics.

Profile of Hubei's population growth, economic development and environmental quality: According to the sixth national census, Hubei's resident population was 57, 237, 740 (with 0:00 on November 1, 2010 as the standard point). The province's household population is 61, 759, 720 (including accounts pending). Comparing with the end of 2000 which was 59, 359, 897 there was an increase of 4.04%. Data shows that population growth was in low birth rate stage for the decade.

According to statistical data, the average annual growth rate of population was 63.78 million, with an average annual growth rate of 1.21%. As for the distribution of resident population from 1981-2012, urban resident population had increased and the proportion of rural resident population had declined. In 1981, the urban population occupied 16.79% of Hubei's total resident population and by 2012, the proportion reached 46.0%. This showed that the rapid economic and social development had promoted the urban population increases and the increasing the mobility. On the other hand, it illustrated that the process of urbanization involved more rural residents into urban residents' ranges.

Since, the reform and open-up, Hubei's economy has experienced a rapid growth. From 1985-2012, the nominal GDP had grown by 56.15 times, with an average annual growth of 17.48%. Real GDP (based on the price of 1985, the same below) increased by 15.02 times. Real per capita GDP grew 12.88 times, with an average annual growth rate of 12.2%. Three industrial structures had been optimized. In 2012, the proportion of the output value of three industries was 12.8:50.3:36.9. According to Chenery's theory of division, Hubei was in the middle stage of industrialization.

In 2012, Hubei's economy maintained steady and rapid growth. GDP reached 2.225045 trillion Yuan, increased by 11.3% than the previous year. The annual per capita disposable income of urban residents reached 20,840 Yuan, increased by 11.8 %. As can be seen from the above statistics, Hubei is during the period of rapid development.

As "the province with thousand lakes", Hubei has 29 major lakes, the surface area is approximately 1585.9 km^2. With economic development and industrial restructuring, lake water pollution once intensified. In recent years, with the government's effort, water quality was overall stable and part of the regional water quality was improved.

In 2012, Hubei's water which met the criteria of class 1-3 accounted for 86.6% (which was 85.1% in 2011) increased by 1.5% significantly better than the overall level of water quality in the seven major river systems (the national ratio meeting class 1-3 standard was 59.6%). The water quality of Yangtze River and Han River was generally excellent and Yangtze River's water quality had improved markedly, rising from 2011's favorable to 2012's excellent. The water quality of Han River was light polluted. The rate that Lake and reservoir water quality met or exceeded grade 3 was 54.5 %, flat compared with 2011.

As for air quality, in 2012, the average percentage of the 17 major cities' days of good air quality was 92.7% which was 94.2% in 2011. Hubei also has air pollution problem. In 2012, the proportion of city with acid rain was 44.4 %.The figure was flat comparing with 2011. The average acid rain frequency was 27.6%, increased by 1.1%.

In 2012, the ecological environment quality index was 70.00, decreased by 0.73 % than the previous year. The environment quality was favorable, better than the national environmental quality which was at normal level.

Interaction analysis

Interaction between Hubei's population and economy: In general, moderate population is necessary for a region's economic and social development. In an agricultural society and the initial stage of industrial society, output depends more on the quantity of simple labor time. Therefore, population growth has an important role for economic development. In addition, the production depends on consumption and the population also determines the size of the market. At a certain level of economic development, the population means greater market potential and thus a stimulus to economic development. Currently, most of the world's countries and regions, especially the less-developed areas, population growth will undoubtedly bring enormous economic and social development impact. First, rapid population growth will affect the quality of population. For a single family, since the size is too large, the investment in each child will be reduced, thus affecting education, quality of life, etc. Second, rapid population growth has led to inadequate macroeconomic education, health care and infrastructure investment. So, it is worse for the formation of human capital, thus lowering economic sustainability. Third, population growth accelerates accumulation and migration. The rapid expansion of urban population will cause many social problems, such as traffic, housing shortage, environmental pollution, public disorder etc. Finally, overpopulation may cause employment difficulties and increasing social instability.

Multivariate regression of the relations between Hubei's population growth and economic development of Hubei relations: As for the indicators measuring population growth and economic development, this article divides the indicators into two different systems, population index and economic index. The former includes Total Population (TP), Urban Population (UP) and Rural Population (RP). The latter includes Gross Domestic Product (GDP), Per capita GDP (PGDP), Ratio of Secondary Industry output (SIR) and Ratio of Tertiary Industry output (TIR).

In order to analyze the relationship between demographic indicators and economic indicators, this article chooses demographic indicators as independent variables while main economic indicators (i.e., GDP) as dependent variable to make a multiple regression. As for the analysis of impact of economic development on population, using economic indicators as independent variables while the main demographic indicators (i.e., the total population) as the dependent variable to make a multiple regression.

Different elements of the indices tend to have different units and dimensions and numerical variation may be very different which will have an impact on the evaluation results. Therefore, the data dimensionless processing is necessary. The most common method is poor standardization Eq. 1:

$$X_{ij} = \frac{x_{ij} - \min\{x_{ij}\}}{\max\{x_{ij}\} - \min\{x_{ij}\}} \quad (i = 1, 2, \ldots, m;\ j = 1, 2, \ldots n) \qquad (1)$$

Among the equation, X_{ij} is the original value for the index; min $\{X_{ij}\}$ is the minimum of the indicator, max $\{X_{ij}\}$ is the maximum value. After standardization, the maximum is 1, the minimum is 0 and the remaining values are between 0 and 1. Here select total population, urban population, rural population, GDP, per capita GDP from 1983 to 2012 to make dimensionless process.

Create the following regression model Eq. 2:

$$Y = X\beta + \varepsilon \qquad (2)$$

Among the model, Y is the main economic indicators (i.e., GDP), X is demographic indicators, namely, X = [TP, UP, RP, I]^T, $\beta = [\beta_1, \beta_2, \beta_3, \beta^0]^T$ are the vector of regression coefficients to be determined, for ε is regression error.

The regression results are shown in Table 1.

The significance test state $R^2 = 0.7560$, $F = 26.8465$, $p = 0.0197 > 0.01$. The residual vector after regression and confidence intervals is plotted a bar chart (Fig. 1).

The residual distribution indicates that residuals confidence level of the 25th and 30th group data does not include zero, so the data should be removed. After that, there are still some data's residual confidence intervals excluding zero. When removing more data (the last five sets of data from 2008 to 2012), the regression results are as Table 2.

Table 1: Regression results of model 2

Regression coefficient estimates	99% of significance level
$\hat{\beta}_1 = -0.2777$	-1.2387, 0.6832
$\hat{\beta}_2 = 0.8205$	-0.3513, 1.9922
$\hat{\beta}_3 = -0.2485$	-0.7617, 0.2647
$\hat{\beta}_0 = 0.1493$	-0.3174, 0.6159

Table 2: Regression results of modified model 2

Regression coefficient estimates	99% of significance level
$\hat{\beta}_1 = 0.3571$	-0.0152, 0.7295
$\hat{\beta}_2 = -0.0928$	-0.5550, 0.3695
$\hat{\beta}_3 = -0.2847$	-0.4740, -0.0953
$\hat{\beta}_0 = 0.2031$	0.0308, 0.3754

Fig. 1: Multiple regression residuals plot of main population and economic indicators

Fig. 2: Multiple regression residuals plot of main economic and population indicators

Table 3: Regression results of model 3

Regression coefficient estimates	99% of significance level
$\hat{\alpha}_1$ = 3.4698	-7.1440, 14.0836
$\hat{\alpha}_2$ = -3.1996	-13.8211, 7.42190
$\hat{\alpha}_3$ = -1.4970	-3.4097, 0.41570
$\hat{\alpha}_4$ = 2.9523	2.2831, 3.62140
$\hat{\alpha}_0$ = 0.2342	-0.6509, 1.11930

Through significance test, $R^2 = 0.9256$, $F = 87.0920$, $p = 0.0014<0.01$.It can be seen that the regression coefficient is significant, so model 2 was established.

These results indicate that during the earlier 25 years, the impact of Hubei's population growth on economic development can be described by multiple regression equation. But after 2007, the rapid economic development of Hubei Province has not only presented a simple linear relationship with population growth.

Regression model of Hubei's economic development on population growth: Create the following regression model Eq. 3:

$$Y = X\alpha+\varepsilon \quad (3)$$

Y is the main demographic indicator (i.e., the total population), X is economic indicators, namely, $X = [GDP, PCG, SIR, TIR, 1]^T$, $\alpha = [\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_0]^T$ are the vector of regression coefficients to be determined, ε is the regression error. The regression results are as Table 3.

The results of significance test show $R^2 = 0.9728$, $F = 223.5831$, $p = 0.0035<0.01$. The error bar chart is as Fig. 2. The data confidence interval contains zero. This shows that the regression coefficient is significant, so that the model 3 is established.

These results indicate that we can use the multiple regression equation to describe the economic development on the population Eq. 4:

$$Y = 3.4698X_1-3.1996X_2-1.4970X_3+2.9523X_4+0.2342 \quad (4)$$

Among the equation, Y is total population, is economic indicators, namely $[X_1, X_2, X_3, X_4]^T = [GDP, PCG, SIR, TIR]^T$.

Interactions between Hubei's economy and environment: Environmental system provides resources for economic development and it is the fundamental guarantee. Humanity needs to survive, so we must have basic necessities of life which requires economic development. The various ingredients are from natural environment. Economic development also has an impact on the environment. As long as resources are being used, it will generate environmental problems. The resource conversion efficiency is lower when technical level can't be improved in time. If more and more waste being discharged, the environment will be greatly changed. Environment has self-purification system. But if the waste on the environment highly beyond the ability of self-purification, it will result in environmental pollution problems, even lead to the collapse of environmental systems.

Regression analysis of the relationship between Hubei's economic development and environmental quality: For the measurement of economic development and environment of selected quantitative indicators, this article divides

economic and environmental indicators into two different indicators system. The former includes Per capita GDP (PGDP) and Ratio of Secondary Industry output (SIR). The latter includes Total Volume of Waste Water Discharged (TWV), Total Volume of Industrial Waste Water Discharged (IWV), Total Volume of Waste Gas Discharged (TGV), Volume of Sulfur Dioxide (SDV), Volume of Industrial Dust (IDV) and Volume of Industrial Solid Wastes Produced (ISV).

Given the economic indicators, a more reasonable approach is converting an annual per capita GDP based on price index, thus eliminate the impact of price increases or currency fluctuations on GDP. According to the price index in the Statistical Yearbook, real per capita GDP from 1996 to 2012 can be calculated. As for the environmental indicators; we still retain its initial statistics, in agreement with previous studies in order to compare the results.

Regression model of relationship between Hubei's per capita GDP and environmental quality: According to the least square principle, we use the model to make curve fitting for the real per capita GDP and environmental indicators. The fitting results are shown in Fig. 3.

These curves above are three fitting results of real per capita GDP and environmental indicators. Seen from the fitted curve, as per capita income levels increase, wastewater emissions fluctuate and it reaches a minimum value when real per capita GDP near 6000-7000 Yuan. Once Hubei greatly invested in wastewater treatment and has achieved favorable results. The trend of fitting curve reflected the fact. Over the past two years, wastewater emissions had a certain degree of rise. Industrial wastewater emissions presented a downward trend. Emissions and industrial SO_2 increased as per capita GDP increased. But it can be seen from the slope of the curve that the growth rate had been slowing down. According to the available data, it still cannot predict that whether the amount of exhaust and industrial emissions would decrease. Industrial dust and industrial solid waste emissions reached the highest value as real per capita GDP was around 4000-5000 Yuan. And it steadily declined as per capita GDP increased.

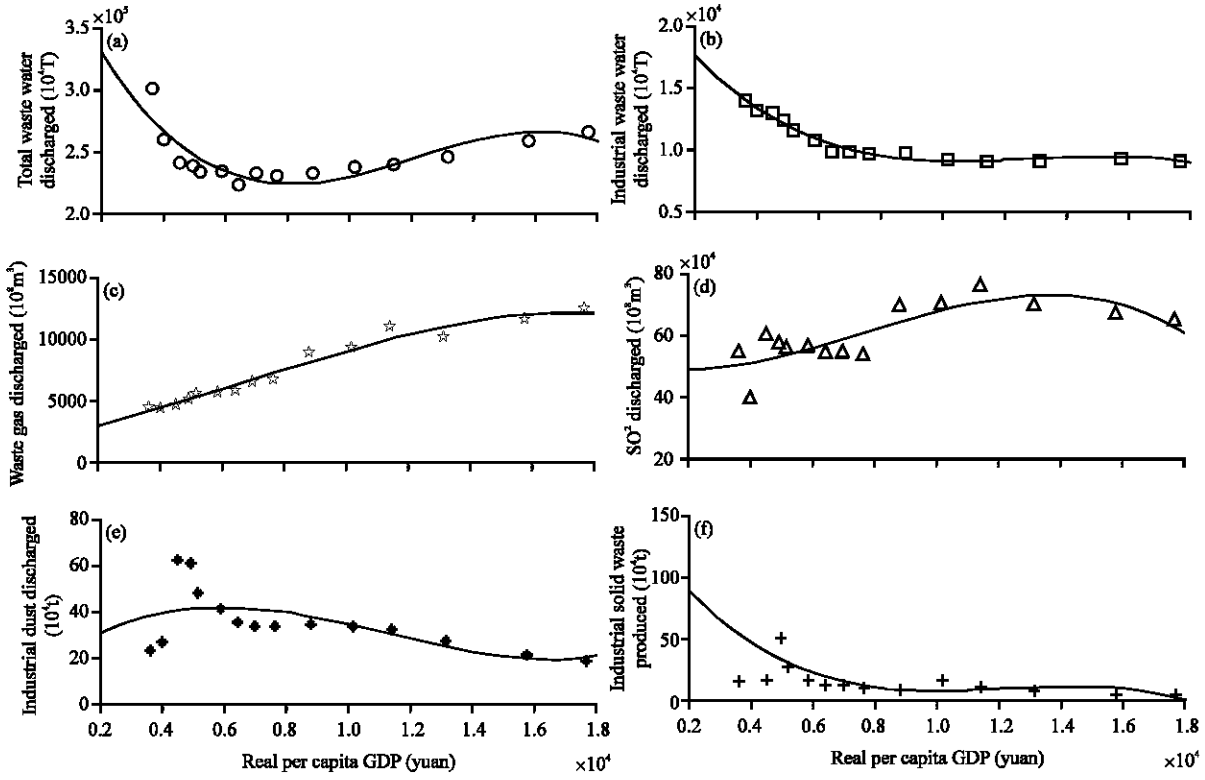

Fig. 3(a-f): Fitting results of per capita GDP and environmental indicators of Hubei (in 1995 prices) per capita GDP, (a) Total wastewater discharged, (b) Industiral wastewater discharged, (c) Waste gas discharged, (d) SO_2 discharged, (e) Industiral dust discharged and (f) Industiral solid wastes produced

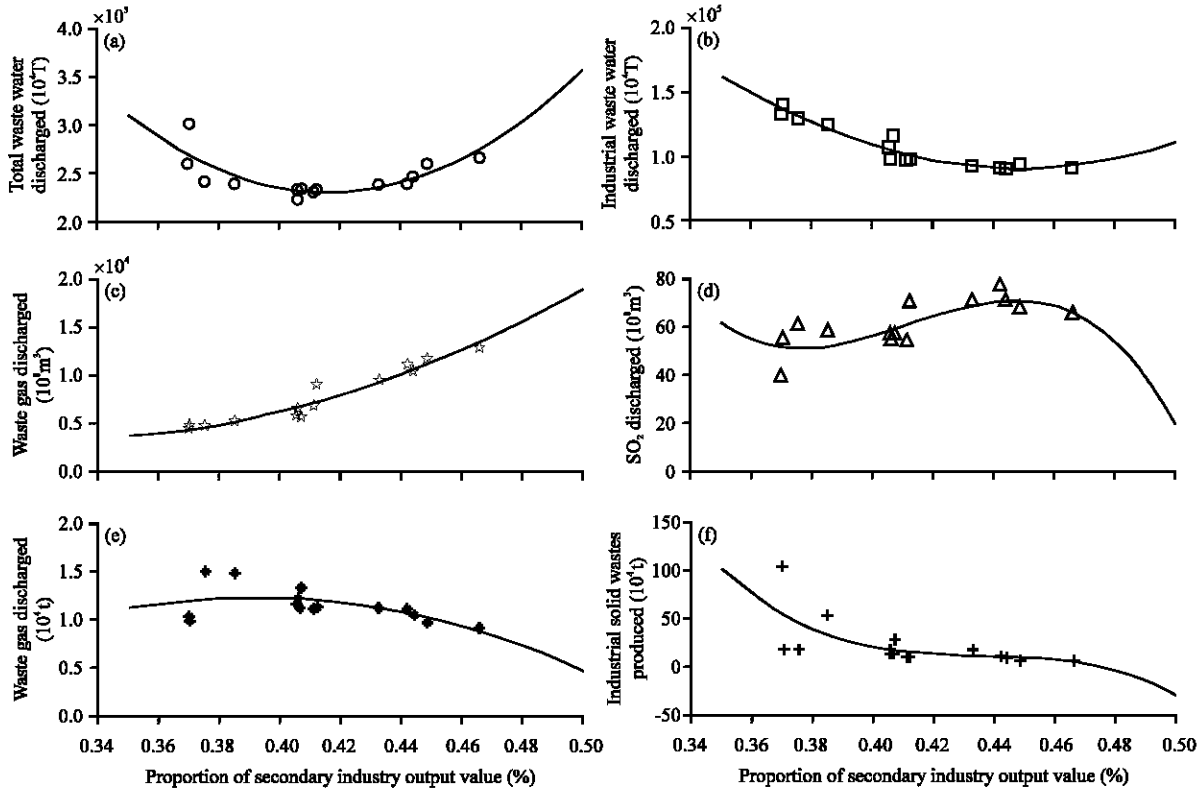

Fig. 4(a-f): Fitting results of second industrial proportion and environmental indicators of Hubei proportion of secondary industry output value, (a) Total waste water discharged, (b) Industrial waste water discharged, (c) Waste gas discharged, (d) SO_2 discharged, (e) Industrial dust discharged and (f) Solid wastes produced

Regression model of the relationship between the proportion of secondary industry output value and environmental quality: Using model to fit the proportion of secondary industry output value and environmental indicators, fitting results are as shown in Fig. 4.

From the fitted curve, the relationship between the proportion of secondary industry output value and industrial wastewater emissions first decreased and then showed increasing trend which reflects industrial structure adjustment during the process of industrialization. In the earlier period of industrial development, Hubei took advantage of its abundant water resources, resulting in higher wastewater emissions. Followed by the industrial structure adjustment and pollution control policies, pollution reduced. Emissions and industrial SO_2 increased as the proportion of secondary industry output value increased, suggesting that the air pollution control is insufficient. Industrial dust emissions and industrial solid waste when the secondary industry output value accounted for 36-38 % reached the highest value and then it gradually declined. It related to adjustment of industrial structure and technology improvement in dust and solid waste comprehensive utilization.

CONCLUSION

From above, the developmental level of Hubei province is in the intermediate stage of industrialization. Although the increasing rate is lower, the natural growth rate is still high. The economic development of Hubei has made significant achievements. Economic development has influenced the population distribution and increased demand for resources, resulting in increased pollution emissions. From the indicators of waste water emission and industrial exhaust gas, it can be seen that the extensive economic growth pattern still existed. In view of the above problems, this article puts forward the following suggestions:

- The government should focus on pollution prevention and take the recycling economy road of new industrialization. It should actively guide enterprises to take the new road to industrialization from the concept of circular economy which means high technological content, good economic returns, low resource consumption etc.
- Strengthen industrial waste water and emissions control and increase investment in environmental protection
- Strengthen sewage supervision and establish a scientific and efficient supervision system. The sewage shall be jointly supervised by the government and the public

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