An analysis on the environmental Kuznets curve of Chengdu

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Abstract: In this paper based on the environmental and economic data of Chengdu from 2005 to 2014, the measurement models were established to analyze 3 kinds of environmental flow indicators and 4 kinds of environmental stock indicators to obtain their EKC evolution trajectories and characters. The results show that the relationship curve between the discharge of SO_2 from industry and the GDP per capita is a positive U shape, just as the curve between discharge of COD from industry and the GDP per person. The relationship curve between the dust discharge from industry and the GDP per capita is an inverted N shape. In the central of the urban the relationship curve between the concentration of SO_2 in the air and the GDP per person is a positive U shape. The relationship curves between the concentration of NO_2 in the air and the GDP per person, between the concentration of the particulate matters and the GDP per person, and between the concentration of the fallen dusts and the GDP per person are fluctuating. So the EKC curves of the 7 kinds of environmental indicators are not accord with inverted U shape feature. In the development of this urban the environmental problems can't be resolved only by economic growth. The discharge of industrial pollutants should be controlled to improve the atmospheric environmental quality and reduce the environmental risks.

1. Introduction

Since the reform and opening up, Chinese economy has rapidly grown, and the cities developed quickly. The urbanization rate increased from 36.22% of 2000 to 51.27% of 2011, and during 10 years the urbanization rate rose by 13.46%. With the urbanization of the economy, society and technology developed, environmental problems appeared, such as atmospheric pollution, water pollution, noise pollution and so on. In 2010, there are 30 cities of the 113 environmental priority cities, whose air quality did not meet the national secondary standards. The 113 cities discharged 37 billion tons of waste water, which were 60.0% of the country's wastewater emissions. Obviously, the cities' rapid development has brought significant pressure on the urban environment.

2. Material and Methods

Material Chengdu is located in the southwest of China. It is the important social, economic and cultural center in this region. It has been developing rapidly in recent years. The urban growth rates of Chengdu grew by 12.5% from 2000 to 2010, up nearly five percentage points from 2010 to 2012, and it stays in the acceleration of urbanization. However, with the rapid urbanization the environment is not positive. There are traffic jams, highlighted shortage of water because of pollution [1], and high content of fine particulate matters in the atmosphere [2]. Because there are air pollution [4], water pollution and soil pollution [5] [6], though the city harmoniously developed on the whole, the environment lagged [7]. In order to research the coupling mechanism between the urban economic growth and environmental pressure, the environmental and economic data from 2005 to 2014 was

accumulated, and based on the theory of environmental kuznets curve, the measurement model between economic growth and environmental cost was constructed. By this model this article analyzes the coordination way between environmental protection and economic development in order to prompt the decoupling between economic growth and environmental pressure as soon as possible.

Environmental Kuznets Curve Theory In 1990s, American economist Grossman and Krueger found that environmental degradation levels rose up first and then declined as the income level rose up, which was like an inverted u-shaped curve. It is known as environmental Kuznets curve (EKC). "Environmental Kuznets curve" shows that with the economic development environmental problems gradually increase, then gradually decrease and eventually disappear [8-12]. So it is considered that environmental problems can be solved depended on economic growth. Empirical researches showed that there was not only inverted u-shaped relationship between environmental indicators and income level, but also U shaped relationship, N shaped relationship (inverted N relationship) and synchronous relationship [13-15]. As a result, environmental problems sometimes can be exacerbated as economic growth and cannot be resolved effectively. Even though they are inverted u-shaped relationship, when the environmental damage caused by unreasonable economic development is beyond the local environmental carrying capacity, the turning point of inverted u-shaped curve will never be reached. Therefore, cities in the process of rapid development need to coordinate the environment and economy.

Environmental Kuznets Curve Model The measurement model of EKC is usually characterized by linear functions, quadratic polynomials, three polynomials, log functions, and exponential functions. The most commonly used functions of a second function, three functions, and logarithms are as following:

$$Y = a_0 + a_1 x + a_2 x^2 + e \quad (1\text{-}1)$$

$$Y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + e \quad (1\text{-}2)$$

$$Y = a_0 + a_1 (\ln x) + a_2 (\ln x)^2 + e \quad (1\text{-}3)$$

Among them, Y is the environmental indicators, x is the GDP per capita, a_1, a_2, and a_3 are the coefficients or constants, and e is the random perturbation.

3. Results and discussion

The simulated industrial emissions EKC curves and analyses The pollution in cities is mainly caused by emissions in the process of economic production. The economic structure of Chengdu is dominated by the second and third industries. The second industry is larger than the third industry, and the environmental pollutants mainly come from the second industry. In order to study the relationship between economic growth and discharge of pollutants, we chose the discharge of Chengdu's industrial SO_2, industrial dust and industrial COD from 2005 to 2014 in Chinese environment statistical yearbook. By the social and economic statistical yearbook of Chengdu from 2005 to 2014, the GDP per capita of the whole city is gotten as the GDP per capita.

According to the data, with GDP per capita as the abscissa, SO_2 emission as the ordinate, the EKC curve was drawn, and simulated by a quadratic curve. The results are shown in figure 1. Similarly, the EKC curve of the industrial dust emission was simulated by a cubic curve, and the EKC curve of industrial COD emission was simulated by a quadratic curve. The results were shown in figure 2 and figure 3.

The values of R^2 in above curves are greater than 0.85, indicating that the simulated curves are fit to the actual statistical data well. The EKC curves of industrial SO_2 emissions and the industrial COD emissions are positive u-shape. Industrial SO_2 emission is the lowest when the GDP per capita is 76667 Yuan and industrial COD emission is lowest when the GDP per capita is 75000 Yuan. Now the two kinds of emissions are currently located near the flat bottom of the curve. The EKC curve of the industrial dust emissions is N shape. If the time span is narrowed, it can be observed that the current EKC curve went through the maximum value of the inverted u-shaped curve, and then enter into the

right side of the inverted u-shaped curve. It shows that with the increase of GDP per capita emissions reduce. All of the above show that the three kinds of flow pollutants have been effectively controlled in recent years. This is the result of adjusting the industrial structure and carrying out clean production in recent years. Due to the reduced proportion of the first and the second industry, increasing the proportion of the tertiary industry, the GDP increased, but industrial emissions of pollutants increase not much even in gradually reduce.

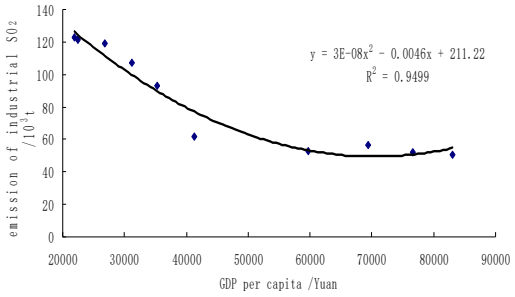

Figure 1 the EKC of industrial SO_2 emission

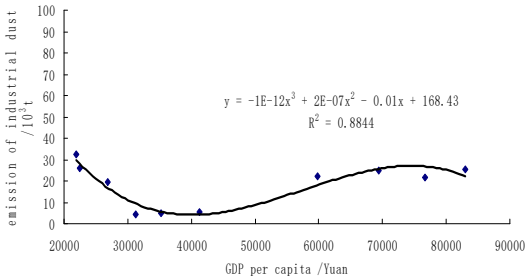

Figure 2 the EKC of industrial dust emission

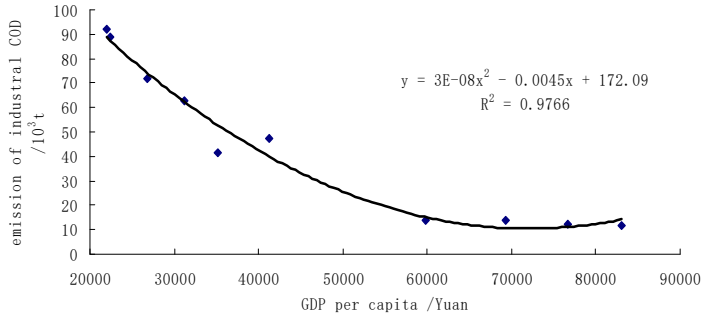

Figure 3 the EKC of industrial COD emission

The simulated urban atmospheric EKC curves and analysis In perspective of the urban environmental quality, because the urban water pollutants can be accommodated by the water outside of the urban, the pollution is to a certain extent controlled. Because of the geographical and meteorological conditions in the basin, the outer space sharing ability for air pollutants is limited. The urban atmospheric pollution is serious. Four indicators, such as the concentration of SO_2, NO_2, PM10, and the quantity of fall dust, are selected from the environment quality bulletin of Chengdu from2005 to 2014. According to the statistical yearbook of Chengdu from 2005 to 2005 the GDP per capita can be calculated. Then the relationship between the actual urban environmental quality and the GDP per capita was discussed in the following.

With the GDP per capita of the urban as the abscissa, the concentration of SO_2, NO_2 and PM10 and the quantity of dust fall as the ordinate, environmental kuznets curve (as shown in figure 4, figure 5, figure6, and figure 7) can be plotted. The EKC of SO_2 can be simulated by a quadratic curve. It's a positively u-shaped curve similar to the EKC curve of SO_2 emissions. The concentration of SO_2 is minimal when the GDP per capita is 100000 Yuan. Current concentration is near the bottom of the curve. The EKC of NO_2, PM10 and dust fall quantity can be simulated by a quintic curve. The curve is undulating waves and fluctuations. The above simulations show that the kuznets curves of urban atmospheric quality in the urban of chengdu is not inverted u-shape, and the urban atmospheric quality can't be improved by itself with the increase of GDP.

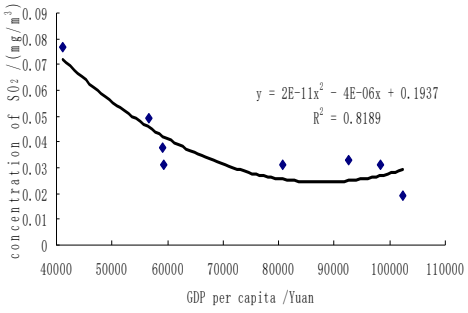

Figure 4 the EKC of SO_2 concentration

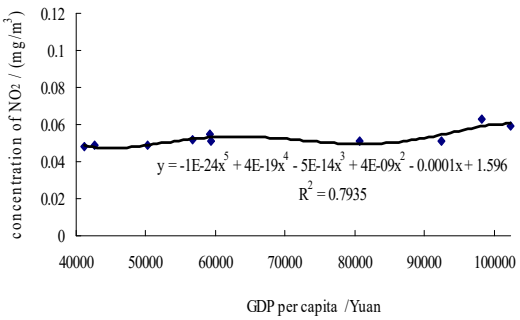

Figure 5 the EKC of NO_2 concentration

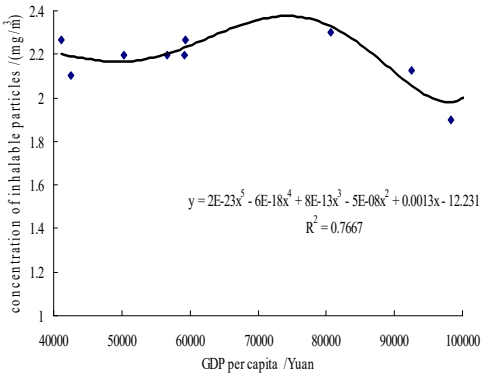

Figure 6 the EKC of inhalable particle concentration

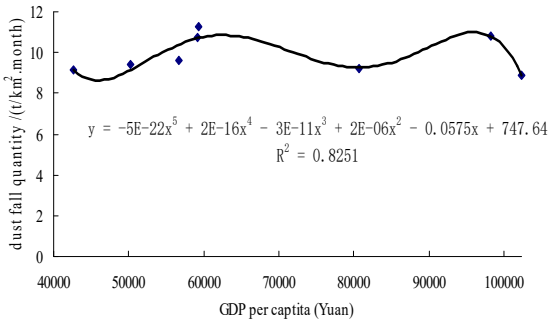

Figure 7 the EKC of dust fall quantity

4. Conclusion

Based on the theory of environmental Kuznets curve, the relationship between the environment and the economy in urban development is analyzed, and the following conclusion is acquired:

Because the environmental Kuznets curves of industrial SO_2 emissions and COD emissions are positively u-shape, although the two kinds of pollutants emissions are in the slow growth stage at present, there is a risk of pollutants increase with economic growth. Industrial dust emissions recently are in the downtrend. As a result, Chengdu should strengthen its control of industrial exhaust emissions during the economic development process, maintain low emission levels and avoid environmental risk. For industrial dust emissions the downtrend should be kept, running on the right side of the Kuznets curve, making the urban environment sustainable.

The environmental Kuznets curves of the urban air quality don't accord with the u-shaped curve, and there is a risk of atmospheric environmental degradation in urban growth. The environmental Kuznets curves of the urban SO_2 concentration and industrial SO_2 emissions are positively u-shape. The environmental Kuznets curves of NO_2, PM10 and dust fall are quintic curve. So urban SO_2 concentration is associated with industrial SO_2 emissions, and there is no obvious relevance between the rest pollutant concentration and industrial emissions. The atmospheric environmental quality is more affected by geographical environment, the influence of other factors such as weather conditions. Therefore, in order to ensure the sustainable development of Chengdu, the industrial pollutant discharge not only needs to be controlled, but also the investment in environmental governance needs to be increased, avoiding urban ecological risk because of SO_2, NO_2, PM10 and dust increase.

In this paper the environmental Kuznets curves of Chengdu are simulated and analyzed and the conclusion is the basis of further study of urban environmental economy. But restricted by data, the environmental economic data from 2005 to 2014 are analyzed. The time scale is limited. It's necessary to lengthen the time scales in the further study, in order to improve the results of the study.

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