Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 13	No. 1	pp. 151-158	2014

Original Research Paper

The Verification of SO_2 Environmental Kuznets Curve (EKC) in China Based on the Provincial Panel Data During the Tenth and the Eleventh Five-Year

Chen Feng, Xi Wenyi*, Liu Peng, Li Yufei and Shi Lei
School of Environment and Natural Resources, Renmin University of China, Haidian District, Beijing, 100872, PR China
*Nicholas School of the Environment, Duke University, Durham NC, USA
Corresponding Author: Shi Lei

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 24-12-2013
Accepted: 26-1-2014

Key Words:
Air pollution
Sulfur dioxide
Environmental Kuznets curve

ABSTRACT

China's air pollution problem has become more serious and the impacts of various pollutants staggered. As the pollutant sources and the consequences of pollution are various, different governance measures have been taken for different pollutants. Meanwhile, the Environmental Kuznets Curve as a theoretical description of the environmental pollution and the level of economic development, its specific form is still to be demonstrated in practice. As an air pollutant with serious consequences, sulphur dioxide started being controlled in the last century. During the "Eleventh Five-Year Plan" period, the government has focused a special object on this project. Through the study of sulphur dioxide Environmental Kuznets Curve, this paper concludes that the country's sulphur dioxide emission has reached a situation where its emissions have increased rapidly with the economic development, but later entered a slow growth or a gradual decline, and in this process, the proportion of secondary industry and the foreign trade has a significant impact on the emission of sulphur dioxide. The paper provides a reference for the study of other air pollutants emission paths and counter measures.

INTRODUCTION

During the past thirty years, China experienced a rapid economical growth while encountering numerous environmental problems at the same time. The Chinese government has adopted "Protect the Environment" as a fundamental national strategy, and devoted increasing amount of money and other supporting policies to solving the problems.

The Environmental Kuznets Curve (EKC) reflects the relationship between the environmental pollution and economic development. As an inverted U-shaped curve, the EKC means the pollution increasing along with the economic growth at first, and then declines after the economic development arrives at certain turning point. This is because the pollution will result in more serious environmental accidents which threaten the safety of the public, thus the society will begin to pay more attention to the environmental quality, not focusing only on the economy. Since the EKC describes the trend of the overall environmental quality, the situation of specific environmental elements, for instance, the air quality could also be indicated by this curve.

The air quality of China is a hot issue over the years, and sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NOx) and particulate matters (PM) are considered as the most common pollutants. As is well known, acid rain, which is caused by the severe air pollution, mainly SO_2 and NOx is a typical environmental problem that brings many negative effects such as the damage to the human respiratory system and the erosion of buildings. In view of this serious situation, the policy makers have prepared different policies and time tables against SO_2 emissions, for example, the China's 11th Five-Year Plan (2006-2010). The statistics from the National Bureau of Statistics suggest that the total emission of SO_2 in 2010 was about 2.2 million tons decreasing significantly from 2005 when the emission was 2.5 million tons. This unambiguous decrease hence leads to several interesting questions: Is this dropping trend of SO2 emissions is due to adopting the relevant reduction measures, e.g. the 11th Five-Year Plan, or is it simply an occasional phenomenon that the emission happened to decrease because of the normal fluctuation? Furthermore, does this kind of change of the SO_2 emission level follow the EKC? Does the EKC exist in China? And if exists, what is the turning point of the economic development? Especially within the past ten years, the government announced that some positive improvements have been achieved after the huge efforts and investments in the environmental industry, among which is the SO_2 control. Therefore, this paper intends to solely focus on SO_2 and discuss about the following two main issues: 1. The virtual relationship between the economics and SO_2 emissions, and some high-order functions containing quadratic and cubic terms that can possibly represent this relationship; 2. Other factors besides the commonly known Gross Domestic Production (GDP) that could affect the SO_2 emissions, and the standards of choosing the right factors to reduce the emission.

Since some people argue that the Environmental Kuznets Curve may only exist theoretically, it is meaningful to use the real data to verify its practical existence. In this paper, the panel data of 30 provinces in China from 2000 to 2010 were collected, and the econometric methods were applied to the verification process. One point that needs to notice is the conclusion of this analysis that the EKC may only fit for the situation of China, which may not be applicable to other pollutants or other counties. However, this paper can still provide certain implications for readers who are interested in the complex relationship between the economics and the environment in methodological level and theoretical level.

EARLIER STUDIES

The EKC of air pollution started much earlier and has applied various methods. As to the research method, Halkos (2003) collected the data of SO_2 emissions and GDP of total 73 countries (both OECD and Non-OECD countries) from 1969 to 1990, by using the Random Effect Model and Generalized Method of Moments (GMM), the existence of inverted U-shaped Environmental Kuznets Curve could not be rejected but still lacking sufficient evidences to prove the curve's shape. In addition, the result estimated that the turning point of SO_2 emissions is around \$2805 to \$6320. Begun & Eicher (2008) applied the Bayesian Model Averaging (BMA) to verify the EKC of SO_2 concluding that there was little evidence to support its existence. He (2010) used the provincial level SO_2 emission intensity of 13 industrial sectors during the period of 1991-2001 to explain how trade openness affects aggregate industrial SO_2 emission and that the industrial composition transformation process played a key role in the rise in pollution in most Chinese provinces. As to the relevant theory and application of EKC, Suri & Chapman (1998) studied the pooled cross-country and time-series data and indicated that the increasing export trade would significantly increase the SO_2 emissions of both industrialized and industrializing countries since the export trade interferes with their energy consumption. Rafa (2006) tested the curve by analysing the following aspects: 1. EKC's theoretical basis, 2. Technical problems of SO_2 emissions, 3. The kind of information used for estimation, 4. The change of the structure of electricity production, 5. Improvements of energy efficiency, and 6. The application of cleaning mechanism. The results indicated that even though EKC exists, its application as an instrument for policy design still needs further considerations. Regarding the study of EKC in specific countries, Park & Lee (2011) focused on 16 metropolitan regions by collecting the data of 16 years. However, they found that each region has a different shape of the curve, rather than a unified EKC of SO_2, which suggests each region should implement different policies for different pollutants. Yaguchi et al. (2007) found a notable decreasing trend of SO_2 emissions in Japan but an unclear trend of the SO_2 emissions in China by comparing these two countries. The analysis of the air quality and main pollutants of China conducted by Brajer (2011) infers that China's SO_2 emissions has already stepped into the downward phase.

The domestic study on the EKC of SO_2 emissions also started early, and most of them solely focus on the situation of China with both advantages and disadvantages. Liang (2012) worked on quadratic function, cubic function and quartic function respectively by employing the data of industrial SO_2 emissions per capita and GDP per capita from 1991 to 2010, and the model was finally proved to have an M-shaped curve. This study only considers the impact of economic factors on the industrial SO_2 emissions which ignores other possible factors. Wang & Li (2008) considered SO_2 emissions per capita as the dependent variable, and chose explanatory variables by including each region's economic growth rate, GDP per capita indicating the economic development, average energy consumption per unit of GDP indicating the development of technology, and a variable stringency of local government's environmental policy. According to the Hausman test, the model is eligible for exerting the fixed effect on cubic function, and the EKC is eventually estimated as inverted N-shaped. Xie et al. (2012) selected several indicators, such as SO_2 emissions of each province, total GDP, total foreign direct investment (from individual ownership, cooperative enterprise and joint ventures), capital-labour ratio, and the ratio of SO_2 removal to SO_2 emissions. They took the fixed effect into account, run the regression model by including the square of total GDP, and then compared the situation of central and western areas of China through separate models. The results support the existence of the EKC, and indicate that foreign direct investment contributes to the decrease of SO_2 emissions, especially in the midwest regions. However, this analysis did not study the cubic function, and neglected the factor of population as total SO_2 emissions and total GDP were directly utilized to estimate the model.

Compared to previous studies, the innovations of this study are as follows: 1. As considering the factor of increasing population, most of the indicators are divided by population, hence obtaining the per capita data, such as SO_2 emissions per capita, GDP per capita. 2. This analysis includes comprehensive factors that would affect the amount of SO_2, that is, not only the ones that influence emissions, such as GDP, foreign trade and the ratio of the secondary industry, but also the factors that interfere with the removal of SO_2, for example, the investment in pollution control which also reflects the implementation of relevant policies. 3. The data are collected from 2000 to 2010, which cover the periods of the 10th and 11th Five-Year Plan, and especially the 11th Five-Year Plan emphasized on the reduction of SO_2 emissions. In addition, almost all the provinces of China are included so that more effective policies could be suggested regarding different regions. 4. The regression models are estimated by containing quadratic terms and cubic terms respectively which fully expand the equation. The quadratic function is tested here to research whether there is other trend before or after a simple U-shaped or inverted U-shaped curve. The Hausman test is also conducted to decide whether the fixed effect should be applied in the model.

METHODOLOGY AND DATA

Model construction-variable selection: In this procedure, firstly, from the time dimension, this paper collects the data between 2000 and 2010, which cover the tenth and eleventh national five-year plan of China. The eleventh five-year (2006-2010) is the most important reduction period of China against SO_2 (National Ministry of Environmental Protection 2010).

As the purpose of this paper is to verify the existence of the EKC and to probe the specific form of the EKC, it should contain variables that can reflect the SO_2 emissions and the economic development. The SO_2 emission is represented by SO_2 emissions per capita and the economic development is indicated by GDP per capita. As the China Statistical Yearbook calculates the life SO_2 emissions and the industrial SO_2 emissions separately, the SO_2 emission per capita equals to the sum of life SO_2 emission per capita and industrial SO_2 emissions per capita. Meanwhile, GDP per capita is actually represented by the Gross Regional Production (GRP) per capita because this analysis collects the panel data of different provinces.

In view of the previous studies, besides the SO_2 emissions and the economy development, there are other factors that can influence the shape of the EKC: 1) Trade. As a developing country, the goods exported from China have the characteristics of low labour value-added and high resource-consumed. If considering the transfer of pollution, China will be in an even unfavourable position. The empirical researches have shown that no matter industrializing countries or industrialized countries, once the exportation of manufactured goods increases, the energy consumption of the country will increase accordingly, hence, the pollutant emissions will be higher than before (Suri & Chapman 1998). 2) Industry Structure. The secondary industry accounts for a high percentage of the industry structure in China, and since the industrial coal is the biggest emission source of SO_2, this unbalanced industry structure certainly has an impact on the SO_2 emission. According to the estimate, 87% of the total SO_2 emission is from burning coal in 2000 and 67.2% of which is from industrial coal (Wang et al. 2002). Moreover, as is seen from the China Statistical Yearbook, the industrial SO_2 emission is significantly much higher than the life SO_2 emission (National Bureau of Statistics, 2000-2010). Therefore, the industry structure could be regarded as an important influencing factor. 3) Investment in pollution control. The amount of SO_2 emissions is decided by the generation and removal of SO_2, especially in the industrial sector. This is because most reduction technologies are applied to the industrial sectors, while seldom to the people's life since the life SO_2 emissions are too scattered to control (Zheng 2001). Judging from the experience, if the trade and the industry structure could affect the generation of SO_2, then the investment in pollution control may be the main factor influencing the removal of SO_2. The reason why this variable is included in this paper is that in China, it is believed that the emission of SO_2 will affect the policy intense but won't stimulate the investment against pollution. Based on above, all the variables and indexes utilized in this paper are summarized in Table 1.

The form of the model: When constructing the model, the real situation of how SO_2 emission changes should be reflected. However, in fact, all the high-order functions can lead to an inverted U-shaped EKC, and the second-order, third-order and fourth-order functions are all have been discussed in the previous studies (Liang 2012, Xie et al. 2012). Considering that the fourth-order or higher-order function would appear to have more than one peak and valley which actually cannot happen in China currently, this paper thereby focuses on the verification of quadratic and cubic function. The function estimated in this paper is shown as below:

$$\ln E = \beta_0 + \beta_1 \ln GDP^3 + \beta_2 \ln GDP^2 + \beta_3 \ln GDP + \beta_4 \ln T + \beta_5 \ln IS + \beta_6 \ln IV + U_2 \quad ...(1)$$

The equation (1) reveals the relationship between the SO_2 emissions and other explanatory variables. When $\beta_1 = 0$, it is a quadratic function; while $\beta_1 \neq 0$, it is a cubic function. In this equation, lnE represents SO_2 emissions, lnGDP represents economic development, lnT represents trade, lnIS represents industry structure, and lnIV represents pollution control.

The relationship between the value of the coefficients and the shape of the curve is given in Table 2.

Data: Regarding the variables in equation (1), this paper calculates the values of these variables by referencing the data from China Statistical Yearbook (National Bureau of Statis-

Table 1: Variables and relevant indexes.

Variable	Index
SO_2 Emission	SO_2 emission per capita
Economy Development	GDP per capita
Trade	Export per capita
Industry Structure	2^{nd} industry percentage
Pollution Control	Investment in industrial air pollutants control per capita

Table 2: The relationship between the value of the coefficients and the shape of the curve.

The value of the coefficients	Shape of the curve
$\beta_1 - 0,\ \beta_2 - 0,\ \beta_3 \neq 0$	Linear
$\beta_1 - 0,\ \beta_2 > 0, \beta_3 < 0$	U-shaped
$\beta_1 - 0,\ \beta_2 < 0, \beta_3 > 0$	Inverted U-shaped
$\beta_1 > 0, \beta_2 < 0, \beta_3 > 0$	N-shaped
$\beta_1 < 0, \beta_2 > 0, \beta_3 < 0$	Inverted N-shaped

Table 3: The outcome of stationary test.

Variables	LLC test	IPS test	ADF-Fisher test	PP-Fisher test
lnE	-3.7884***	-1.0717	77.2979*	37.7024
lnGDP	8.0248	13.8624	19.6383	4.3453
lnT	-2.9323***	2.9912	27.3996	30.5841
lnIS	-3.1019***	1.2593	55.9647	62.1995
lnIV	-4.7715***	-0.7385	67.6758	52.9235
ΔlnE	-6.6647***	-3.5201***	100.4309***	90.2293 ***
ΔlnGDP	-10.4549***	-3.5564***	102.2210***	103.8649 ***
ΔlnT	-13.7987***	-8.4986***	188.2758***	221.2309 ***
ΔlnIS	-12.8466***	-6.7096***	159.8035***	194.0375 ***
ΔlnIV	-13.6344***	-7.4186***	169.1754***	181.6891 ***

Notes: (***),(**),(*) indicate that the estimates are statistically significant at the 99%, 95% and 90% levels respectively.

tics, CEInet). All the economic data have been adjusted to the prices based on 2000.

SO_2 emissions per capita: Since the yearbook does not list the direct SO_2 emissions per capita, the paper uses the sum of the industrial SO_2 emissions and life SO_2 emissions which is then divided by the population to obtain the final value.

GDP per capita: This index can be found in the yearbook directly, and here the data are adjusted by comparable prices in order to remove the fluctuation of the prices between different years.

Export per capita: In this paper, exportation per capita equals to the quotient of the export calculated by the location of the business units and the population of that region. Similarly, this index is adjusted by the comparable price.

Secondary industry percentage: This paper employs the proportion of the added value in secondary industry to the added value in GDP as the secondary industry percentage. Since it is a coefficient of proportionality, there is no need to further adjust the variable.

Investment in pollutants control per capita: This variable is calculated by dividing the amount of completed investment in pollution control of industrial emissions with the population of every province, because the control of SO_2 emission is mainly applied to the industrial sectors (Jia 2005). In addition, this index also needs to be adjusted by the comparable price.

After the variables been calculated by the indexes, in order to eliminate the time trend, all the data are transformed to the logarithm. The equations of the calculation are as below:

ln E = In (Industrial SO_2 emission + Life SO_2 emission)/ Population) ...(2)

lnGDP = ln (GDP per capita) . ...(3)

lnT = ln (Exportation categorised by the location of the business units/Regional population) ...(4)

lsIS + ln (Added value in the secondary industry/Added value in GDP × 100) ...(5)

lnIV + ln (Completed amount of investment in pollution control of industrial emissions/Regional population) ...(6)

EMPIRICAL ANALYSIS

Stationary test of the data: Normally, the time series data have to pass the stationary test before conducting the regression. Since this paper employs the pooled panel data, stationary test is also required for this analysis. In some cases, non-stationary data may show the common changing trends, while in fact they have no direct relationship. Therefore, the regression of these data is less meaningful even though high R-squared could be achieved. This phenomenon is called false regression or spurious regression which could be avoided by conducting the stationary test, and unit-root test is the most common method of the stationary test. Specifically, four different ways of the unit-root test are used in

Table 4: The outcome of co-integration test.

Variable	Statistics
Pedroni Residual Panel v-Statistic	-2.4784
Pedroni Residual Panel rho-Statistic	4.1860
Pedroni Residual Panel -pp	-4.6539***
Pedroni Residual Panel -ADF	-3.6137***
Group rho-Statistic	6.3804
Group PP-Statistic	-8.4143***
Group ADF-Statistic	-3.3991***
Kao Residual -ADF	-5.2709***

Notes: (***), (**), (*) indicate the estimates are statistically significant at the 99%, 95% and 90% levels respectively.

Table 5: The outcome of Hausman test.

	(b) fe	(B) re	(b-B) Difference
lnGDP	1.381478	1.28241	0.0990676
$lnGDP^2$	-0.18203	-0.1677	-0.0143304
lnIS	0.75928	0.853349	-0.0940683
lnT	0.118764	0.086134	0.0326303
lnIV	0.021225	0.031195	-0.0099705

Test: Ho: difference in coefficients not systematic
$Chi^2(5)$ = (b-B)'[(V_b-V_B)^(-1)](b-B) = 26.39
Prob > chi^2 = 0.0001***; (V_b-V_B is not positive definite)
Notes: (***),(**),(*) indicate the estimates are statistically significant at the 99%, 95% and 90% levels respectively.

Table 6: Regression of the second-order equation. [F(5,295) = 39.92; Prob > F = 0.00]

lne	Coef.	Std.Err.	t	P>|t|
lnGDP	1.3815***	0.2354	5.8700	0.0000
$lnGDP^2$	-0.1820***	0.0278	-6.5500	0.0000
lnIS	0.7593***	0.1494	5.0800	0.0000
lnT	0.1188***	0.0355	3.3500	0.0010
lnIV	0.0212	0.0150	1.4200	0.1580
_Cons	-3.0763***	0.5450	-5.6400	0.0000

Notes: (***),(**),(*) indicate the estimates are statistically significant at the 99%, 95% and 90% levels respectively.

Table 7: Regression of the third-order equation. [F(6,294) = 36.33; Prob > F = 0.0000]

lne	Coef.	Std.Err.	t	P>|t|
lnGDP	-2.7014***	1.2324	-2.1900	0.0290
$lnGDP^2$	0.8556***	0.3088	2.7700	0.0060
$lnGDP^3$	-0.0859***	0.0255	-3.3700	0.0010
lnIS	0.5945***	0.1548	3.8400	0.0000
lnT	0.1188***	0.0349	3.4100	0.0010
lnIV	0.0222	0.0147	1.5000	0.1340
_Cons	2.7832	1.8180	1.5300	0.1270

Notes: (***),(**),(*) indicate the estimates are statistically significant at the 99%, 95% and 90% levels respectively.

this analysis, that is, LLC, IPS, ADF-fisher and PP-fisher test. The outcome of Eviews 7.2 is given in Table 3.

The outcome shows that, under the I(0) condition and 5% significance level, variables lnE, lnT, lnIS, and lnIV only pass the LLC test but are rejected by all the other three tests, while the variable lnGDP is denied by all the four tests. Thus, it can be concluded that all the five variables are non-stationary under the I(0) condition. Whereas, under the I(1) condition and 5% significance level, these five variables passed all the four tests, and hence can be considered as stationary under the 1st difference. Based on the outcome of stationary test, the above variables are stable at the same order, and could be utilized to run the regression effectively.

Co-integration test of the data: In order to examine the co-integration of the data, this analysis uses the panel co-integration test proposed by Pedroni together with the Kao Residual-ADF co-integration test, by building eight statistics based on the regression residuals. Considering the selected data has a relatively small sample, and the statistics of Panel ADF and Group ADF in Pedroni test are more suitable for small-sample data, and the results of the Panel ADF and Group ADF could provide more valuable implications. The outcome of the co-integration test is given in Table 4.

As indicated in Table 4, the statistics of Pedroni Residual Panel-PP, Pedroni Residual Panel-ADF, Group PP-Statistics, Group ADF-Statistics and Kao Residual-ADF, all pass the co-integration test under 5% significant level. Therefore, this small-sample data have the characteristics of co-integration, and are eligible for panel regression.

Model estimation: Panel regression can normally be estimated by either using the fixed effect model (FE) or the random effect model (RE), and different methods would-result in different regress equations. Usually, Hausman test is used to examine the applicability of RE. The outcome of Hausman test is presented in Table 5.

From this test outcome, this paper should utilize the fixed effect model to regress the quadratic and cubic function. The results of the regression models are shown in Table 6 and Table 7.

As can be seen from the Table 6 and Table 7, the coefficient of the constant term in the third-order equation and the coefficient of variable lnIV in both functions are not significant. Since the variable lnIV is insignificant in both equations, the model is run again without this variable. Therefore, from a statistical point of view, the quadratic function is more reasonable than the cubic function. The result of the final model is given in Table 8.

This final model not only passes the joint F test, but also includes the variables that all have significant coefficients,

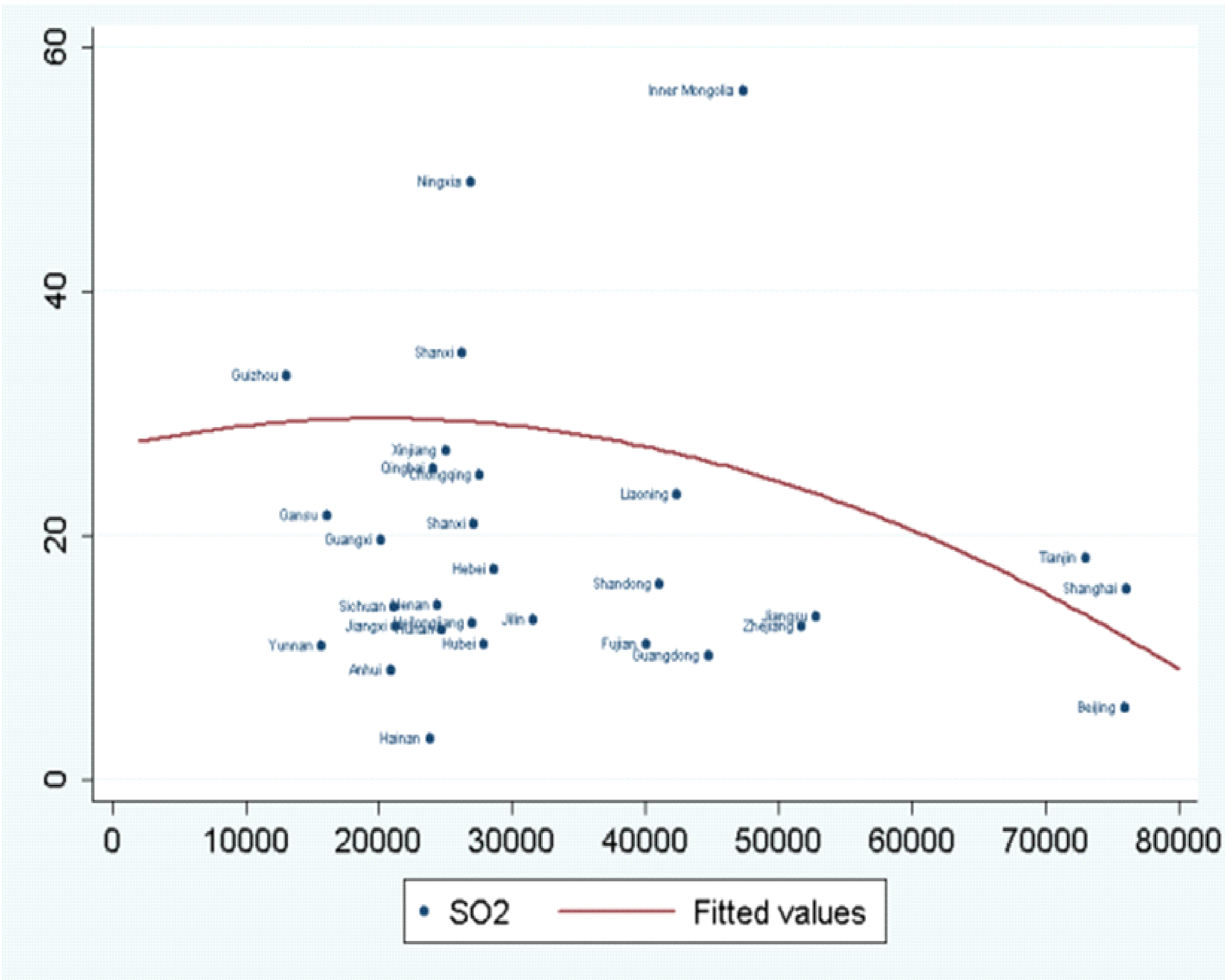

Fig. 1: Distribution of each province and the predicted EKC.

which is then utilized for the further analysis.

CONCLUSION

The equation for the EKC of SO2 emissions in China can be expressed as below.

$$\ln E = 3.2431 - 0.184 \ln GDP^2 + 1.4097 \ln GDP + 0.1247 \ln T + 0.7976 \ln S + U_2 \quad ...(7)$$

The turning point of this EKC is between \$1218.41 and \$5063.17 per capita (RMB: 7676-31898 Yuan). Based on this conclusion, further studies of regions with different economic level are continued in order to provide corresponding suggestions.

As can be seen, the red line indicates the predicted EKC of China, which can be categorized into three phases: Phase A showing that SO_2 emissions increase along with the growing economic level, Phase B surrounding the turning point, and Phase C represents the downward phase that SO_2 emissions begin to decrease. The distribution of those dots implying all the provinces in China have passed the phase A, and only Beijing, Shanghai, Tianjin, Jiangsu, Zhejiang, Guangdong, Inner Mongolia, Liaoning, Shandong and Fujian, these ten provinces have entered the phase C. Most provinces are still remaining in the Phase B that whether they have achieved the peak amount of the SO2 emissions or start entering into the downward phase is not sure yet, which needs further verification. Based on above situations, four main conclusions and corresponding suggestions could be obtained.

1. Supported by the regression result, the EKC of SO_2 emis-

Table 8: Regression of final model. [F(4,296) = 49.23; Prob > F = 0.0000]

lne	Coef.	Std.Err.	t	P>|t|
lnGDP	1.4097***	0.2349	6.0000	0.0000
lnGDP²	-0.1840***	0.0278	-6.6200	0.0000
lnIS	0.7976***	0.1472	5.4200	0.0000
lnT	0.1247***	0.0353	3.5300	0.0000
_Cons	-3.2431***	0.5330	-6.0800	0.0000

Notes: (***),(**),(*) indicate the estimates are statistically significant at the 99%, 95% and 90% levels respectively.

sions is proved to exist in China, and is affected by not only GDP, but also each region's exporting trade and industrial structure. Meanwhile, the SO_2 emissions in China indeed follow the trend of the Environmental Kuznets Curve, i.e., at first, the SO_2 emissions per capita rise as the GDP per capita rises, and then decrease after the turning point, which presents as an inverted U-shaped curve.

2. All the provinces in China have passed the upward phase (Phase A), but only some regions have entered into the downward phase (Phase C). The majority of provinces are around the turning point, which have unclear changing trend in the future. Some still expand the emissions of SO_2 gradually, while some have started dropping the emissions, which may possibly get rebounded at some time.

3. Regarding the provinces and regions at the Phase C, the future development pathway still needs to maintain the 11th Five-Year period's policies that the economic growth should be combined with economic restructuring in order to further control the SO_2 emissions. In addition, even though these ten provinces have stepped into the downward phase, the differences between each province are obvious. For example, the position of Inner Mongolia is much higher than the position of other provinces at the same phase. This is because, on the one hand, its percentage of the secondary industry is as high as 54.9%; on the other hand, Inner Mongolia is one of the largest province of the coal production and coal consumption, thereby leading to a more advanced coal related chemical industry which is a direct source of SO_2 emissions. As a result, to maintain the decreasing trend of SO_2 emissions, these provinces should keep optimizing the economic structure, regulating the export of goods, and gradually eliminating the low value-added and highly polluted products.

4. As to the provinces at the Phase B, they should pay attention to the following two aspects: (1) These provinces need to shorten the time achieving the peak emissions, or achieve the peak emissions at lower GDP level. In order words, they should reach the turning point as soon as possible. Especially for provinces which have inferior per capita level of economic development, such as, Guizhou and Yunnan, the developing pathway of some antecedent provinces should be avoided. Moreover, from now, they should strictly control the pollution, actively change the structure of energy consumption and prioritize the development of industries with less pollution, so that the economic development could be accelerated and the theoretical peak emission level could be achieved quickly. (2) These provinces should not only reach the turning point earlier, but also try to lower the peak amount of SO_2 emissions. For example, provinces, such as, Ningxia and Shanxi, which are above the predicted curve, should reduce their SO_2 emissions to the average level of other provinces at the same phase. In terms of lowering the peak emissions, it can be accomplished by optimizing the industrial structure, reducing the proportion of the secondary industry, and lessening the export of highly polluted and low value-added goods. China is currently still under the rapid development, which is an appropriate stage for reducing its dependence on export trade and stimulating the domestic demand to develop the economics. And only products with both export advantages and characteristics of economic and environmental sustainability should be kept for this transitional stage. Therefore, the faster the provinces at phase B, achieve the peak SO_2 emissions, the greater need for these provinces to optimize their export structures.

REFERENCES

Begun, J. and Eicher, T.S. 2008. In search of an environmental Kuznets Curve in sulfur dioxide concentrations: A Bayesian model averaging approach. Environ. Dev. Econ., 13(6): 795-822.

Brajer, V., Mead, R.W. and Xiao, F. 2011. Searching for an environmental Kuznets Curve in China's air pollution. China Econ. Rev., 22(3): 383-397.

Halkos, G.E. 2003. Environmental Kuznets Curve for sulfur: Evidence using GMM estimation and random coefficient panel data models. Environ. Dev. Econ., 8(4): 581-601.

He, J. 2010. What is the role of openness for China's aggregate industrial SO_2 emission?: A structural analysis based on the Divisia decomposition method. Ecol. Econ., 69(4): 868-886.

Jayanthakumaran, K., Verma, R. and Liu, Y. 2012. CO_2 emissions, energy consumption, trade and income: A comparative analysis of China and India. Energy Policy, 42(3): 450-460.

Jia, X. 2005. Sulfur dioxide controlling methods review. Gansu Science and Technology, 21(12):138-139.

Liang, H. 2012. The relationship between industrial sulfur dioxide pollution and economic growth: An empirical study based on panel data. Journal of Wuyi University, 26(4): 59-65.

Park, S. and Lee, Y. 2011. Regional model of EKC for air pollution: Evidence from the Republic of Korea. Energy Policy, 39(10): 5840-5849.

Rafa, B. 2006. A skeptical vision of the environmental Kuznets curve: The case of sulfur dioxide. Int. J. Sustain. Dev. World Ecol., 6(12): 513-524.

Suri, V. and Chapman, D. 1998. Economic growth, trade and energy: implications for the environmental Kuznets curve. Ecol. Econ., 25(2): 195-208.

Wang, S., Wang, Q., Zou, F. and Yu, Y. 2002. The contaminative situation of sulfur dioxide in China and suggested control countermeasures against it. Journal of Xinyang Agricultural College, 12(3): 20-21.

Wang, X. and Li, D. 2008. The study on the characters of sulfur emission in the process of economical growth in China. Ecological Economy, 2: 261-264.

Xie, S., Wang, X. and Huang, B. 2012. Economic growth, the way of FDI and emissions of SO_2 in China: An analysis on Chinese Provincial Panel data 2003-2009. Word Economy Study, 4: 64-70.

Yaguchi, Y., Sonobe, T. and Otsuka, K. 2007. Beyond the environmental Kuznets curve: A comparative study of SO_2 and CO_2 emissions between Japan and China. Environ. Dev. Econ., 12(3): 445-470.

Zheng, B. 2001. Sulfur dioxide pollution and its solution. Fujian Environment, 18(3): 13-15.

Zhu, Y., Zhang, P. and Niu, H. 2012. The Environmental Kuznets curve research and analysis based on the econometrics. Contemporary Economy & Management, 34(7): 5-12.