Consilience: The Journal of Sustainable Development
Vol. 4, Iss. 1 (2010), Pp. 60–79

An Analysis of Economic Growth and Industrial Wastewater Pollution Relations in China

Hong Yang*
Swiss Federal Institute for Aquatic Science and Technology
Duebendorf, Switzerland*

Yuan Zhou
Swiss Federal Institute for Aquatic Science and Technology
Duebendorf, Switzerland

Karim C Abbaspour
Swiss Federal Institute for Aquatic Science and Technology
Duebendorf, Switzerland

Abstract

This paper investigates the relationship between income growth and the trend in industrial wastewater discharge in China during the period 1981-2007. For the data encompassing all the provinces over the entire period considered, both an inverted U-shaped EKC and an N-shaped EKC are statistically significant. An analysis dividing provinces into rich and poor groups reveals that the EKC relations are mainly governed by the rich province group. The EKC relations for the poor province group are either not found or are statistically weak. A further analysis based on dividing the data into before and after the year 2000 is in favour of the quadratic EKC model. The results of this study show that the relationships between a given pollutant and income are temporal and spatial specific depending on the driving forces behind. This implies that results derived from one study for certain regions/countries and for a specific time period may not be generalized for other regions/countries and extrapolated to other periods.

Keywords: China; EKC; Industrial wastewater; Panel data.

1. Introduction

China's rapid economic growth at an annual rate of around 10% over the last three decades has not only been unprecedented in its own history but also unique in the world. Both national wealth and living standards have improved tremendously for the majority of citizens. Alongside the rapid economic growth, however, pollution and environmental degradation have become increasingly serious issues. Water pollution is one of the most visible and widespread of these environmental problems. Currently, many rivers and water bodies in the eastern part of the country have water quality levels below Class V, meaning that the water is too polluted to be suitable for any uses.[i] This has further exacerbated the water shortage endured in most parts of the country. Of all the sources of water pollution, industrial wastewater

* Corresponding author, Email: hong.yang@eawag.ch, Fax: +41 44 8235375

has been a significant one, accounting for about 50% of the total wastewater discharge in 2004.[ii]

The sobering water quality situation raises questions about relationships between economic development and environmental pollution. The classical Environmental Kuznets Curve (EKC), which takes an inverted U-shape, describes the pathway of income-pollution relations as such: the environmental quality deteriorates at the early stages of economic development and subsequently improves at the later stages.[iii] In recent years, an N-shaped EKC relationship has been increasingly reported for some pollution indicators, notably CO2. This curve indicates an increase in pollution level after an initial decrease.[iv] In China, studies on the EKC relations started rather recently but have increased rapidly.[v] In the public sphere, the inverted U-shaped EKC hypothesis has often been favourably accepted and used by some to argue the inevitability of deteriorating environment quality with the country's rapid economic growth.[vi] On the other hand, many people have pointed out that China cannot afford to follow the U-shaped path experienced in developed countries because of its limited resources relative to its huge population. China must pursue a 'C-plan,' China's way to decouple economic development from environmental pollution.[vii]

Searching for pathways to decouple economic growth and environmental pollution has been an important motivation behind studies of the pollution-income relation. In the literature, two issues have been tackled the most: whether a given indicator of environmental degradation displays an EKC relationship with per capita income, and the driving forces or causes behind the EKC relationship. Increasingly complicated models and sophisticated statistic software have been applied in these studies.[viii] Studies on the EKC hypothesis have yielded a wide variety of outcomes. In studies considering different pollution indicators, conclusions about the acceptance or rejection of the EKC hypothesis have not agreed. Interestingly, there is a similar discord among studies considering the same pollution indicator. By now, it has been generally recognized that the EKC relationship is just one of many relationships between income changes and pollution.[ix]

Panel data, i.e., combining time-series and cross-sectional data, have been commonly used in empirical studies of the EKC relationship for two major reasons: it provides a rich source of information about the economy and allows greater flexibility in modelling differences in behaviour across individuals; it also overcomes the constraint of short time-series data.[x] Many studies have used cross-country panel data based on the assumption that pollution and income relations are homogenous across countries. This implies that all the countries take the same path in pollution of a given element throughout the course of their economic development. Under this assumption, developed countries will experience a general improvement in the environment after an initial deterioration, while developing countries which are currently witnessing serious environmental deterioration would be expected to reverse this trend after reaching a certain level of income. In recent years, the homogeneity assumption across countries has been widely criticized and proven to be inappropriate.[xi] However, the question of whether or not the assumption could hold for different regions within a country remains. Detailed studies at the country level are often impeded by data limitation on temporal and/or cross-sectional dimensions. China is a large country with substantial regional disparities in economic development and pollution intensity, while the political system and macroeconomic policies are rather homogenous across provinces. It is of theoretical and empirical significance to examine whether or not the homogeneity assumption can be sustained for cross-provincial studies within a country, like China.

This study investigates changes in industrial wastewater pollution with economic development across provinces in China during the period 1981-2007. It specifically examines the heterogeneity in pollution-income relationships between different provincial groups and different periods of observation. Some possible driving forces behind the heterogeneity are also addressed. The focus is on industrial wastewater pollution for a number of reasons. Firstly, China's economic development/growth during the last 30 years has been directly supported by the growth in the industrial sector. Decoupling the linkage between the economic development and industrial wastewater pollution is important for halting the deterioration of water quality. Secondly, the statistics of industrial wastewater pollution have been available since the early 1980s at the national and provincial level. This relatively long time-series provides a more complete course of the changes in industrial wastewater pollution. This has made it possible to address some of the problems caused by short time-series data in the literature. It is worth mentioning the study by Groot et al. (2004), which examined the income-pollution relations applying the provincial data for industrial wastewater discharge from 1982-1997 in China (published in Environment and Development Economics). [xii] Their results rejected the existence of either an inverted U shape or an N-shaped EKC relation during the period they observed. Our study used the same source of data with time period 1981-2007. A comparison of the results from the two studies will provide insight into the pollution-income relations and the driving forces behind them.

In this study, the industrial sector follows the scope defined in China's national GDP accounting. This includes manufacturing, mining and quarrying, thermal power generation, water and gas utilities. It does not include construction. The primary industry, which concerns mainly agriculture; the tertiary industry, which refers to services; and the IT sector are also not in the scope of industry defined in this study.

The rest of the paper is organized as follows: Section 2 provides an overview of the economic growth and the trend in industrial wastewater discharge from the historical and cross-provincial perspectives. Section 3 describes model formulations and data availability. Results from different model and data setups and perspectives are reported in Section 4. Discussions of the results are given in Section 5. Section 6 provides a summary of the findings.

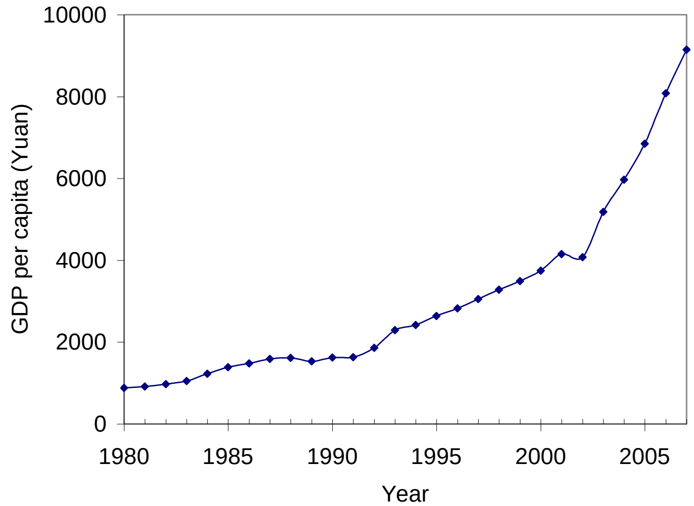

Fig.1 Trend in per capita GDP, 1980-2007

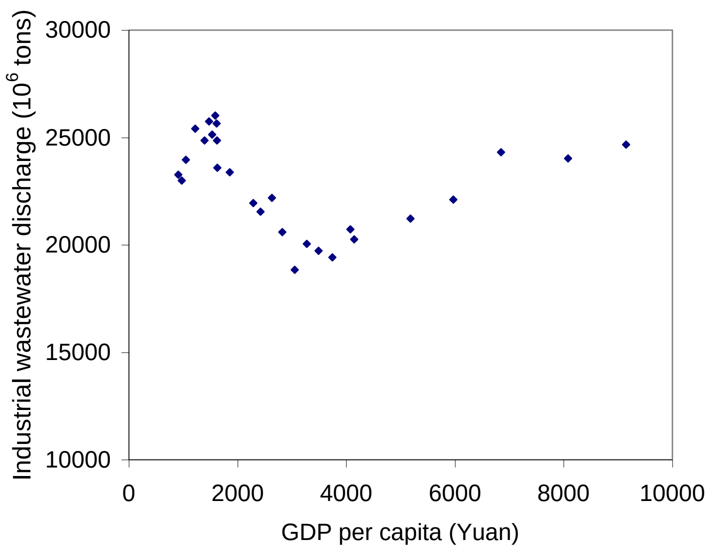

Fig. 2 Total industrial wastewater pollution, 1980-2007

2. An Overview of Industrial Wastewater Pollution

Between 1980 and 2006, the total national GDP increased by about 10 fold and per capita GDP by approximately 800% in real terms (1990 constant prices, unless otherwise specified) (Fig. 1).[xiii] In this process, the industrial sector has played an important role and its share in the national total GDP has been rather stable over the years, around 45%.[xiv] Fig. 2 depicts the trend in total industrial wastewater discharge vis-à-vis per capita GDP between 1981 and 2007. At the national level,

Fig. 3 Per capita GDP by provinces, 2006

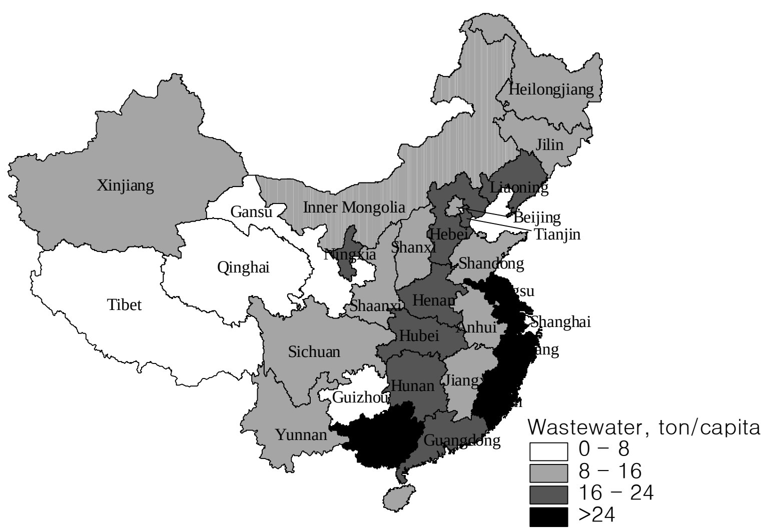

Fig. 4 Per capita industrial wastewater pollution, 2006

after an initial increase, the discharge decreased. However, there was an upturn again in the later years.

Substantial variations exist in economic structure, resources endowment, industrialisation, and urbanisation across provinces. Fig. 3 shows per capita GDP across provinces. High income provinces are concentrated in the eastern-coastal region while the poor provinces lie in the southwest, northwest and part of central China.

The per capita industrial wastewater discharge is shown in Fig. 4. Most of the areas with high discharge are either coastal areas or near the coast where economic development is relatively advanced. In contrast, the lower wastewater discharge is seen in under-developed regions in the northwest and southwest of the country. The income and industrial wastewater discharge appears to have a positive correlation across provinces. This is partly because of the high intensity of industry in the eastern part of the country.

3. Model Specification and Data

3.1 Model specification

There is no consensus on the theoretical background of EKC relations.[xv] After testing several specifications of the econometric equations, such as total pollution, per capita pollution, pollution per unit of production, we chose per capita pollution as the dependent variable. This is partly due to substantial variations across provinces in terms of economic output, population, and population density. Per capita pollution specification provides more consistent and robust statistical results. In addition, if the heterogeneity is significant with the per capita specification, it can be expected that this is also the case for the models with total level of pollution simply because of the large differences in provincial sizes and consequently different scales of the economy and pollution levels.

The choice between linear and log-linear models has been a matter of interest in the econometric literature.[xvi] On conceptual grounds, the first model yields constant marginal effects and variable elasticities, while the second model does the opposite. In the EKC literature, no consensus is reached on which model is better. For the purpose of the present study, the linear model is chosen because of the easy interpretability of the coefficients and computational simplicity, especially when cubic terms are included. We also tested the log-linear model for comparison, and the results are mostly statistically insignificant for the pollution indicators considered.

EKC models have been estimated either in quadratic or in cubic specifications between pollution and per capita income. We adopted both of the specifications in the analysis. In the EKC literature, some studies have included a number of explanatory variables in the model setup. These typically include the consumption of a certain material, e.g., energy, which is a major source of CO_2 emission, economic structure (e.g., share of the secondary industry in total GDP), and population size and density, which are expected to have impacts on pollution intensity.[xvii] In this study, the independent variables only include the linear, square and cubic forms of per capita GDP. The inclusion of some explanatory variables is tested but not reported because they do not seem to improve the model results significantly for this particular case study. Also, we consider that including explanatory variables could be conceptually problematic, because income or per capita GDP in the EKC hypothesis is supposed to be a catch-all variable in which the influence of specified factors, such as economic structural change and technological progress, are embedded.[xviii] Including explanatory variables in the model could lead to double accounting and multi-collinearity problems. In this study, the general forms of the models for panel data are specified below:

$$E_{it} = a_0 + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + u_{it} \tag{1}$$

$$E_{it} = a_0 + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_3 GDP_{it}^3 + u_{it} \tag{2}$$

where E is the level of pollution of a particular water quality indicator in per capita terms. GDP refers to per capita *GDP* at 1990 constant price. The index t denotes year and i refers to province. a_0, β_1, β_2 and β_3 are the parameters to be estimated. If the EKC hypothesis is valid, β_1 and β_3 should be positive and β_2 negative.

The error components, u_{it}, can take different structures.[xix] If the specification depends on cross section, then: $u_{it} = v_i + \varepsilon_{it}$, which is called the "fixed group effects model." If the specification is dependent on both cross section and time series, then the error component follow: $u_{it} = v_i + e_t + \varepsilon_{it}$. This is referred to as a "two-way fixed effects model," taking into account both group and time effects. The term v_i is intended to capture the heterogeneity across groups and the term e_t is to represent the heterogeneity over time. ε_{it} is the classical error term with zero mean and a homoscedastic covariance matrix. Furthermore, if v_i and e_t are treated as random variables, then it is estimated by a random effects model. The nature of the error structures leads to different estimation procedures depending on the specification.

As our panel data include all the provinces in China, treating v_i and e_t as random variables is not warranted (supported by the statistical tests of the estimations). Therefore, fixed effects models are used for all specifications in this study. The group effect, v_i, is a region specific parameter to be estimated, based on the assumption that regions follow a similar pattern of pollution as they develop, albeit at potentially different levels. Controlling for such provincial differences is important as they can greatly influence the location and shape of the income-pollution relationship. Both effects v_i and e_t are tested for their presence and the corresponding F tests are reported. Depending on their presence, the model will take either two-way or one-way fixed effects models. In addition, the heteroskedasticity is controlled for in our estimation by calculating robust standard errors for the coefficients.[xx]

Per capita GDP at the turning point of wastewater pollution can be estimated by differentiating Eq (1) and Eq (2) and setting them to zero. For the quadratic model, the turning point is:

$$GDP_{turning\_point} = -\frac{\beta_1}{2\beta_2} \tag{3}$$

For the cubic model, the upper and lower turning points are:

$$GDP_{turning\_point} = \frac{-\beta_2 \pm \sqrt{\beta_2^{\,2} - 3\beta_1\beta_3}}{3\beta_3} \tag{4}$$

3.2 Data

The data used for this study are taken mostly from Chinese official statistical yearbooks. In general, the socio-economic data are from China Statistical Yearbook, published annually, and all the market values are converted into 1990 constant prices. The data for the industrial wastewater discharge are obtained from various annual editions of China Environmental Statistical Yearbook, which contain information at the national and provincial level. [xxi] The period concerned in this study is from 1981 to 2007 for all the provinces, except for Hainan and Chongqing which gained provincial status in 1987 and 1997, respectively. The panel dataset is thus unbalanced.

Table 1 presents some descriptive statistics on per capita pollution and GDP for the whole panel. We can observe that the mean of industrial wastewater discharge is higher than the median, suggesting the presence of extreme values at the right tail of the data distributions. A more accurate picture of the variability of the panel on its temporal and spatial dimensions is given by the one-way analysis of variance. The data inter- and intra-variation for provinces and years are given in Table 1. For industrial wastewater, the variation is predominantly 'between' provinces while it is higher 'within' years. The results indicate that between-province variation is a major source of variation in our panel.

It is worth noting that underreporting problems is a likely source of error in the available statistics of wastewater pollution as there is a strong incentive for enterprises to underreport or hide the amount of wastewater discharge to avoid paying high pollution fees and fines. Quite often, local governments are reluctant to enforce the environmental standards for the sake of protecting local industries that are the major sources of their revenue. In the meantime, they also tend to underreport the wastewater discharge for maintaining a good political image. Underreporting and deliberately smoothing the amount of discharge over time reduce the likelihood of finding the true shape of the income pollution relationship and lower the model performance. This is particularly so for the time-series analysis

Table 1 Descriptive analysis and analysis of variance for the period 1981-2007

	Industrial wastewater discharge (ton/capita)	GDP (yuan/capita)
Descriptive statistics		
Mean	20.5	3456.6
Median	16.7	2241.0
Standard deviation	15.5	3494.1
Min	0.5	552.0
Max	123.2	28784.0
Analysis of variance		
σ^2_{total}	195638 (100%)	$9.9*10^9$ (100%)
$\sigma^2_{b,i}$ (%)	72.1	38.4
$\sigma^2_{w,i}$ (%)	27.9	61.6
$\sigma^2_{b,t}$ (%)	7.3	42.5
$\sigma^2_{w,t}$ (%)	92.7	57.5

Note: All figures are in per capita terms. Total, between and within variances are given by σ^2_{total}, σ^2_{b} and σ^2_{w}.

because the overall trend in pollution level can be severely distorted. For cross-provincial analysis, however, the problem may be less serious because the underreporting is expected to have a similar magnitude across provinces under the assumption that all enterprises and local authorities have the same incentive to underreport. In this case, the shape of EKC may be less affected, although the constant term in the model may be biased. The awareness of underreporting problems may not help to obtain more reliable data, nor is it easy to account for the degree of error caused in our analysis, as the scale and magnitude of underreporting are unknown. However, the awareness is important for making pertinent interpretations of the modelling results and drawing conclusions on those bases.

4. Results

Table 2 presents the results for industrial wastewater discharge with the quadratic and cubic models. The models are estimated using fixed province and time effects. The reported F tests show statistical relevance of the province-specific and time effects, although differences among provinces are more important than changes within provinces over time. Both the quadratic model and the cubic model are supported by the total dataset and all terms of per capita GDP are statistically significant, and the parameters' signs comply with the EKC hypothesis. The models explain about 87% of the discharge variation as shown by the value of the adjusted R2. For the quadratic model, the turning point calculated using Eq (3) is around 7400 Yuan/capita, from which industrial wastewater discharge begins to decline. The upper turning point for the cubic model calculated using Eq (4) is around 7900 Yuan/capita.

Table 2 Industrial wastewater discharge – income relationships in quadratic and cubic models

	All samples		Rich provinces		Poor provinces	
	Quadratic	Cubic	Quadratic	Cubic	Quadratic	Cubic
GDP	2.26E-03	5.14E-03	2.73E-03	9.74E-03	-1.09E-03	-5.03E-03
	(4.08)***	(4.45)***	(3.03)***	(6.12)***	(-0.68)	(-1.54)
GDP square	-1.53E-07	-3.97E-07	-1.76E-07	-6.97E-07	1.92E-07	1.41E-06
	(-7.80)***	(-3.51)***	(-6.92)***	(-5.27)***	(0.90)	(1.42)
GDP cube		6.16E-12		1.23E-11		-1.10E-10
		(2.10)***		(3.72)***		(-1.18)
Adjusted R^2	0.86	0.87	0.87	0.89	0.79	0.79
No. of observation	811	811	405	405	406	406
Province effects (F test)	99.87	101.74	109.17	108.69	67.23	72.32
Time effects (F test)	22.62	26.83	16.29	21.62	2.82	2.58

Notes: (1) Estimated coefficients of province and time effects are not reported to save space. (2) T statistics from robust standard errors in parenthesis, ***significance at 0.01 level.

Table 3 Quadratic and cubic models for different time periods of the panel

	1981-1999	2000-2007	1981-1999	2000-2007
GDP	3.36E-03	2.68E-03	4.08E-03	2.64E-03
	(5.37)***	(5.33)***	(3.74)***	(2.32)**
GDP square	-5.22E-07	-8.44E-08	-6.56E-07	-8.19E-08
	(-10.04)***	(-6.91)***	(-3.46)**	(-1.23)
GDP cube			6.95E-12	-5.10E-14
			(0.67)	(-0.04)
Adjusted R^2	0.97	0.928	0.97	0.928
No. of observation	563	248	563	248

Notes: (1) The models are estimated with fixed province and time effects. (2) T statistics in parenthesis, ***significance at 0.01 level, **significance at 0.05, *significance at 0.10.

Besides the total dataset, we also modeled sub-samples comprised of high income versus low income provinces with the purpose of testing whether consistent results can be derived from the two sub-groups divided by incomes. The split of the two sub-groups is based on the benchmark value of per capita GDP of 7300 Yuan (roughly the turning point identified above) in the year 2007. Fifteen provinces are categorised as rich while sixteen as comparatively poor. The results show that for the rich provinces, the parameters follow both inverted U-shaped and N shaped patterns. In the case of the low-income provinces, the models have a statistically poor performance (with all the parameters being insignificant) and the signs in terms of per capita GDP appear to be reversed. This suggests that the shape of the curve for industrial wastewater discharge in the whole dataset is predominantly determined by the performance of rich provinces, which are mostly located in the eastern part of China with rapid economic development during the period observed. It may also imply that a relationship between income and total industrial wastewater discharge for poor provinces is yet to be developed or does not exist.

The estimated parameters above seem to suggest a tendency for upturn in the industrial wastewater pollution after an initial decline. To examine the effect of time on the results, we estimated models with different time periods using the year 2000 as demarcation. This division is based on the observation of the national trend in industrial wastewater discharge, which displays a clear upturn trend since 2000 (Fig. 2). The quadratic and cubic models are estimated and the results are shown in Table 3. For the quadratic model, the results for 2000-2007 comply with an inverted U-shaped EKC. For the cubic model, the data for before and after 2000 yield statistically insignificant parameters for total wastewater discharge.

5. Discussion

With the discrepant estimation results for income-pollution relations reported in the previous section, this section provides a discussion on the relations between industrial wastewater discharge and economic development in China. Some insights into the robustness of the EKC hypothesis are elaborated.

To observe the estimated EKC relations visually, we provide figures showing the results from different specifications of models and datasets. Only the model results that are statistically significant are plotted.

Fig. 5 illustrates the curves of quadratic and cubic EKC models, respectively, with the whole dataset. The parameters in the quadratic model appear to be statistically significant and demonstrate the expected signs. The results suggest a strong inverted U-shaped relation between industrial wastewater discharge and income. In the cubic model, the parameters are also statistically significant, indicating an N-shaped relation. Both models show similar turning points.

The division of sub-groups into rich and poor provinces across different time periods aims at investigating the consistency of the model results with different data specifications. In essence, this tests whether the assumption of a common path in pollution-income relations can be sustained in the study within a country.

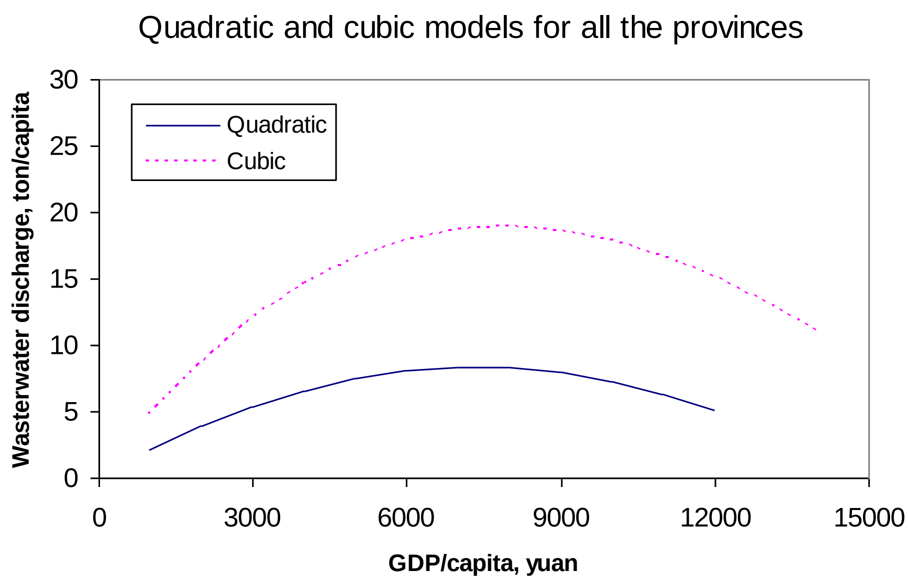

Fig. 5 Quadratic and cubic EKC for the whole dataset

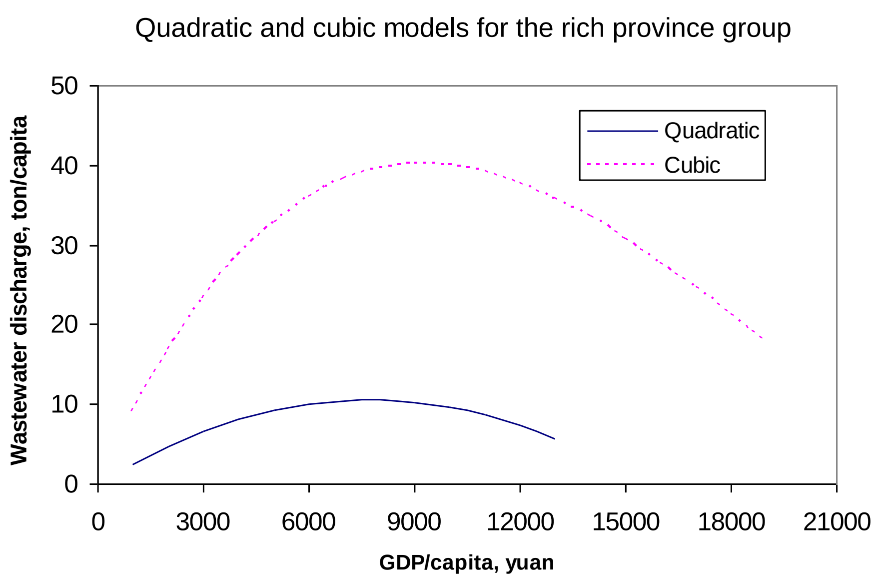

Fig. 6 Quadratic and cubic EKC for the rich province group

The significant difference in the results between the rich and poor provincial groups shown in Table 2 suggests a strong influence of the state of economic development on the pollution-income relations. For the rich province group, the compliance with both an inverted-U shaped and an N shaped EKC implies that a higher income level and a faster economic development lead to a clearer display of the trend in pollution-income relations. Conversely, for the poor province group, the

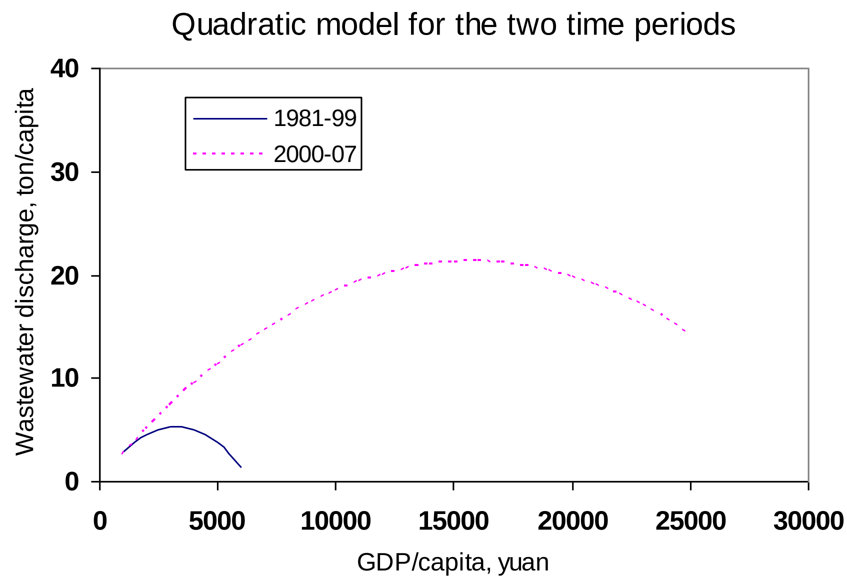

Fig. 7 Quadratic EKC for two time periods: 1981-99 and 2000-07

statistically insignificant parameters are partly the result of a lack of economic development in these provinces, where changes in industrial wastewater pollution are relatively small over the period of observation.

Comparing the results for the rich province group and for all the provinces, it can be seen that the slopes of the EKCs for the rich province group are steeper than those for the dataset of all the provinces. The per capita GDP at the turning point is around 7700 Yuan/year for the rich province group, slightly higher than that for the whole dataset. With Eq. (4), the trough of turning point for the cubic model is estimated to be around 28000 Yuan (in 1990 constant price). So far, only Shanghai has surpassed this income level since 2006.[xxii] However, observing the industrial wastewater discharge per capita for 2006 and 2007 in Shanghai, a second increase in pollution is not observed. This suggests a high uncertainty in the prediction of the pollution-income relations beyond the scope of the majority of the observed data. The results indicate that the inverted-U shaped EKC has been the dominant trend in the industrial wastewater pollution during the period observed. Nevertheless, given the fact that within the rich and poor provincial groups, variations in economic development and industrial structure and resources endowments are significant, different paths in the pollution-income relations can be expected for individual provinces. Moreover, the homogeneity assumption across provinces can be challenged for the study within one country.

The division of the data into before and after 2000 yield different results between the two sub-samples as well as between the sub-periods and the entire period. Only the quadratic model yielded statistically significant parameters for the two time periods, and the results are illustrated in Fig. 7. One of the most distinct features is the much wider range of per capita GDP across provinces in the period 2000-2007 than in the period 1981-1999. This reflects the substantial increase in the regional income inequality during the later years, with the eastern provinces displaying much faster growth than the inland provinces.[xxiii] Another distinct feature shown in Fig. 7 is the substantial difference in per capita GDP at the turning point of the industrial wastewater discharge for the two time periods. For the period 1981-1999, the per capita GDP at the turning point is only around 3200 Yuan/year. For the period 2000-2007, the turning point is around 15800 Yuan/year.

The significant differences between the estimates for the two time periods suggest that the length of the time-series data can have significant impact on the estimation of the EKC. This situation may partly explain the different results in different studies concerning the same or similar pollutant during different periods. In addition, given that one does not know if the data in hand covers the entire course of the income-pollution relations (In most of the cases, it can be expected that the available data do not cover the whole course), any conclusion on the acceptance or rejection of the EKC can only be time period specific, and may not be extended to other periods or generalized. Understanding this is of importance for clarifying variations among studies on the EKC relations for the same pollution indicators. The significance of studying the EKC relations partly lies in its usefulness for describing the course of the pollution and income relationship for a given dataset. However, as the pollution-income relations are dynamic over time, an attempt to find a statistically significant EKC relationship in any time period examined may be not possible or appropriate. For this reason, the utility of the EKC model as an analysis tool for providing a general characterization of pollution-income relations is rather limited.

It is interesting to compare the results from this study with the study by Groot et al. (2004).[xxiv] They examined the income-pollution relations applying the provincial data for industrial wastewater discharge from 1982-1997 in China. The results rejected the existence of either an inverted U-shape or an N-shaped EKC relation during the period they observed, which is approximately the first sub-period (1981-1999) in the present study. As shown in Table 3, all the parameters in the quadratic model are statistically significant, supporting an inverted U-shaped EKC relationship (Fig. 6). Our results, hence, are inconsistent with the conclusion by Groot et al. (2004).[xxv] For testing purposes, we ran the model with the same estimation method and same time period used by Groot (2004).[xxvi] Their results can be reproduced, which means that the inconsistency mainly stemmed from the different estimation methods. Groot et al. (2004) considered only the province-fixed effect, or the so-called one way effects.[xxvii] The autocorrelation was controlled for by regression with AR(1) disturbance. In our estimation, both province-fixed effects and time-fixed effects, (two-way effects) are considered. With this estimation method, autocorrelation is less of an issue since we "dummied out" the time by considering the time-fixed effects. The situation suggests that the results are highly sensitive to the estimation methods used. This raises questions on the robustness of rejecting or accepting an EKC relationship in most studies where conclusions are derived from one specific estimation method favoured by individual authors.

6. Conclusion

This study investigated the EKC relations with respect to industrial wastewater pollution and income changes in China. The EKC relations are modelled with quadratic and cubic models using a panel data approach with different data specifications. In general, both an inverted U-shaped curve and an N-shaped curve are found statistically significant for industrial wastewater discharge.

Breaking the data into rich and poor provinces and different time periods reveals that the shapes of the income-pollution relations derived are often inconsistent between the sub-samples and with the results estimated with the entire sample. Overall, the rich province group has a better compliance with the trend found for the entire dataset. Poor provinces in general do not show a clear pattern in terms of the EKC relations. Inconsistency in the sub-samples for before and after 2000 does not show a clear bias to a particular sub-time period.

In the EKC literature, conflicting results are often derived from different studies. By examining the relationship between income and industrial wastewater discharge in China, this study has shown that the regression results are highly sensitive to the estimation methods, length of time period, and regional specification. The inference is that conflicting results on the shape and turning point of the EKC are inevitable. As there is no consensus on which method and data specification are superior to others, judging which approach is more appropriate and whose results are more accurate is often highly subjective. Any conclusion concerning the pollution-income relationship for a particular pollutant can only be made in the context of the time and space that the study is based on. An important goal of studying pollution-income relations should be to address the driving forces and polices required for generating desired driving forces. Whatever the shapes of the income-pollution relations, one can be sure that the environmental quality will not improve automatically with income increases, but require appropriate policies to generate enabling capacities and incentives to reduce the pollution.

Bibliography

Barbier, B., 1997. Introduction to the Environmental Kuznets Curve. Special Issue. Environment and Development Economics, 2(4):369-381.

Brajer, V., Mead, R., Xiao, F., 2008. Health benefits of tunneling through the Chinese environmental Kuznets curve. Ecological Economics, 66: 674-686.

Bräanlund, R., Ghalwash, T., 2008. The income-pollution relationship and the role of income distributin: An analysis of Swedish household data. Resource and Energy Economies 30: 369-387.

Bruvoll, A., and Medin, H., 2003. Factors behind the environmental Kuznets Curve, a decomposition of the changes in air pollution. Environmental and Resource Economics, 24:27-48.

Canas, A., Ferrao, P., and Conceicao, P., 2003. A new environmental Kuznets curve? relationship between direct material input and income per capita: evidence from industrialized countries. Ecological Economics, 46:217-229.

Criado, C.O., 2008. Temporal and spatial homogeneity in air pollutants panel EKC estimations. Environmental & Resources Economics. 40(2): 265-283.

China Environmental Protection Agency, 1994. China Environmental Statistics, 1981-1990. China Environmental Science Press. Beijing.

Editorial Committee of China Environment Yearbook, 1990, 1991, ..., 2005, 2006. China Environment Yearbook. China Environment Yearbook Press. Beijing.

China Statistical Bureau, 2007. China Statistical Yearbook, China Statistical Press, Beijing.

Cosgrove, W. and Rijsberman, F., 2000. World Water Vision: Making Water Everybody's Business. World Water Council.

Cole, M., 2004. Trade, the pollution haven hypothesis and the environmental Kuznets curve: examining the linkages. Ecological Economics, 48: 71-81.

Dinda, S., 2004. Environmental Kuznets Curve hypothesis: a survey. Ecological Economics, 49: 431-455.

Egli, H. and Steger, T., 2007. A dynamic model of the Environmental Kuznets Curve: turning point and public policy. Environmental & Resource Economics, 36: 15-34.

Galeotti, M. and Lanza, A., 2005. Desperately seeking environmental Kuznets. Environmental Modelling & Software, 20: 1379-1388.

Galeotti, M., Manera, M., Lanza, A., 2009. On the robustness of robustness checks of the Environmental Kuznets Curve hypothesis. Environment and Resources Economics. 42: 551-574.

Greene, W. H., 2003. Econometric Analysis. 5th ed. Upper Saddle River, NJ: Prentice Hall.

Groot, H., Withagen, C., and Zhou, M., 2004. Dynamics of China's regional development and pollution: an investigation into the Environmental Kuznets Curve. Environment and Development Economics, 9: 507-537.

Hettige, H., Mani, M., and Wheller, D., 1997. Industrial pollution in economic development: Kuznets revisited". Working Paper No.1876. Development Research Group, World Bank. <http://econ.worldbank.org/docs/306.pdf> (Oct. 1, 2004).

Jia, S., and Kang, D., 2000. When will freshwater use in China reach the climax? Advances in Water Sciences, 11(4): 470-477.
Jia, S., Yang, H., Zhang, Z., Wang, L. and Xia, J., 2006. Industrial water use Kuznets Curve: evidence from industrialized countries and implications for developing countries. Journal of Water Resources Planning and Management, 132: 183-191.
Khanna, N. and Plassmann, F., 2004. The demand for environmental quality and the environmental Kuznets Curve hypothesis. Ecological Economics, 51: 225-236.
Kuznets, S., 1955. Economic growth and income inequality. American Economic Review, 445, 1-28.
Lieb, C. M., 2003. The environmental Kuznets Curve - a survey of the empirical evidence and of possible causes. Discussion paper series, No. 391. University of Heidelberg.
Lieb, C.M., 2004. The environmental kuznets curve and flow versus stock pollution: The neglect of future damages. Environmental and Resource Economics, 29(4): 483-506.
Liu, X.Z., Heilig, G., Chen, J.M. and Heino, M., 2007. Interactions between economc growth and environmental quality in Shenzhen, China's first special economic zone. Ecological Economics, 62: 559-570.
Martinez-Alier, J., 1995. The environment as a luxury good or 'too poor to be green? Economie Appliquee, 48: 215–30.
Ministry of Water Resources, 2006. China Water Resources Bulletin. Water Conservancy and Hydropower Publisher, Beijing, China.
Muellue-Fuerstenberger, G. and Wagner, M., 2007. Exploring the environmental Kuznets hypothesis: theoretical and econometric problems. Ecological Economics, 62: 648-660.
Munasinghe, M., 1999. Is environmental degradation an inevitable consequence of economic growth: tunneling through the Environmental Kuznets Curve. Ecological Economics, 29(1): 89–109.
Pasche, M., 2002. Technical progress, structural change, and the environmental Kuznets curve. Ecological Economics, 42: 381-389.
Paudel, K., Zapata, H. and Susanto, D., 2005. An empirical test of Environmental Kuznets Curve for water pollution. Environmental & Resources Economics, 31: 325-348.
Shafik, N., 1994. Economic Development and Environmental Quality: An Econometric Analysis. Oxford Economic Papers, 46: 757—777.
Stern, D., 2004. The rise and fall of the Environmental Kuznets Curve. World Development, 32(8): 1419-1439.
Wang, H.W., Zhang, X.L., Wei, S.F., and Kang, H., 2007. Analysis on the coupling law between economic development and the environment in Ürümqi city. Science in China Series D: Earth Sciences, 50: 149-158.
Wang, S.C., 2005. Seminar on developing water saving society. http://www.chinawater.net.cn/minister-new/bzzs.asp?id=20475
White, H., 1980. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. Econometrica, 48: 817-838.
Yandle, B., Bhattarai, M. and Vijayaraghavan, M., 2004. Environmental Kuznets Curve: A Review of Findings, Methods, and Policy Implications, PERC

Research Study 02-1a, April 2004. http://www.perc.org/pdf/rs02_1a.pdf (Oct. 15, 2004).

End Notes

[i] Ministry of Water Resources, 2006

[ii] China Statistical Bureau, 2007

[iii] Shafik, 1994; Hettige et al., 1997; Munasinghe, 1999; Stern, 2004; Yandle et al., 2004; Jia et al., 2006

[iv] Lieb, 2003; Khanna and Plassmann, 2004; Lieb, 2004

[v] Groot et al., 2004; Liu et al., 2007; Wang et al., 2007; Brajer et al., 2008

[vi] Jia and Kang, 2000

[vii] Wang, 2005

[viii] e.g. Bruvoll and Medin, 2003; Canas et al., 2003; Egli and Steger, 2007; Brännlund and Ghalwash, 2008; Galeotti et al., 2009

[ix] Lieb, 2003; Stern, 2004

[x] Greene, 2003

[xi] Lieb, 2003; Dinda, 2004; Stern, 2004; Mueller-Fuerstenberger and Wagner, 2007; Criado, 2008

[xii] Groot et al. 2004

[xiii] China Statistical Bureau, 2007

[xiv] China Statistical Bureau, 2007

[xv] Groot et al., 2004

[xvi] Cole et al., 2004; Galeotti and Lanza, 2005

[xvii] Pasche, 2002; Bruvoll and Medin, 2003; Khanna and Plassmann, 2004

[xviii] Lieb, 2003; Dinda, 2004

[xix] Greene, 2003

[xx] White, 1980

[xxi] China Environmental Protection Agency, 1994; Editorial Committee of China Environment Yearbook, 1990-2007

[xxii] China Statistical Yearbook, 2008

[xxiii] Chinese Statistical Bureau, 2007

[xxiv] Groot et al. 2004

[xxv] Groot et al. 2004

[xxvi] Groot 2004

[xxvii] Groot et al. (2004)