Studies on the Relationship between Environmental Pollution and Economic Growth in China

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Abstract: On the basis of the environmental Kuznets curve hypothesis, this paper applies nonlinear methods to modeling and analyzing the relationship between environmental pollution and economic growth in China, with 29 Chinese provincial data of waste water, solid wastes and waste gas as environmental pollution indexes and per capita GDP as an economic growth index over the period 1989-2009. It is found that nonlinear methods is good in describing the environmental Kuznets curve. The results suggest that with the rise of per capita GDP, per capita waste water emission appears an inverse U-shaped relationship of first increasing and then decreasing, while per capita solid wastes generated and per capita waste gas emission take on the monotonously increasing relationships.

Keywords: Economic Growth; Environmental Pollution; Environmental Kuznets Curve

1 Introduction

A relationship between economic growth and environmental pollution, concretely whether economic growth leads to environmental degradation or improves environmental quality, has been a hot topic in an area of economics and environment science. Large amounts of studies on this income-pollution relation come a common conclusion that environmental degradation first increases with per capita income during the early stages of economic growth, and then declines with per capita income after arriving at a climax, also called threshold or turning point. This process follows a similar pattern to the income inequality pointed out by Kuznets (1955), and so called the Environmental Kuznets Curve (EKC). In general, conventional EKC studies describe the behavior that environmental pollution first aggravates and then alleviates with the rise of economic growth, using standard methods of the linear model or the log-linear model which can be simplified to a polynomial function of income (Grossman and Krueger, 1991, 1993). In this paper, we try to use nonlinear methods which can be used for better describing the EKC relationship, e.g. the Weibull and Gamma specifications by Galeotti and Lanza (2005), and we try to get some implications for the transitional economy such as China.

2 Methods for Describing and Testing for EKC relationship

Now, we present the function forms of Weibull and Gamma for describing the relationship of per capita emission varying with the per capita GDP. They have also been used in applied environmental and ecological economics (Bai et al., 1992), and are widely employed in duration models (Florens et al., 1996). The Weibull function and the Gamma function are both nonlinear functions. Their functional forms can be respectively expressed as follows:

$$y=\frac{\alpha}{\beta}\left(\frac{x-\gamma}{\beta}\right)^{\alpha-1}\exp\left\{-\left(\frac{x-\gamma}{\beta}\right)^{\alpha}\right\} \quad (1)$$

$$y=\frac{1}{\beta\Gamma(\alpha)}\left(\frac{x-\gamma}{\beta}\right)^{\alpha-1}\exp\left\{-\left(\frac{x-\gamma}{\beta}\right)\right\} \quad (2)$$

where α, β and γ are parameters of the Weibull and the Gamma, and so Equation (1) and Equation (2) can be also the three-parameter Weibull and Gamma functions. One advantage of these functional relationships is the interpretability of the parameters: α, β and γ are associated with the "shape", "scale" and "shift" of the functions. The functional relationship can be assumed to be different behavior, depending on the values of the parameters, see Galeottia and Lanza (2005) in detail.

Another advantage of these functional forms is that they admit an analytical closed-form expression for the turning point. In practice, the turning point x^{TP} can be obtained from solving the derivative of y with respect to x in (3) and (4), written as follows:

$$x^{TP} = \gamma + \beta\left(\frac{\alpha-1}{\alpha}\right)^{1/\alpha} \quad (3)$$

$$x^{TP} = \gamma + \beta(\alpha-1) \quad (4)$$

From the expressions of (3) and (4), the turning points of the Weibull and Gamma functions depend on their own three parameters α, β and γ.

Including multiplicative fixed effects and taking natural logarithm in both sides, two nonlinear parametric models can be expressed as:

$$\log E_{it} = \mu_i + \theta_t + (\alpha-1)\log\left(\frac{\mathrm{GDP}_{it}-\gamma}{\beta}\right) - \left(\frac{\mathrm{GDP}_{it}-\gamma}{\beta}\right)^{\alpha} + u_{it} \quad (5)$$

$$\log E_{it} = \mu_i + \theta_t + (\alpha-1)\log\left(\frac{\mathrm{GDP}_{it}-\gamma}{\beta}\right) - \left(\frac{\mathrm{GDP}_{it}-\gamma}{\beta}\right) + v_{it} \quad (6)$$

where the subscript i stands for a region index ($i = 1,\ldots,N$), t is a time index ($t = 1,\ldots,T$). E is per capita emission of one pollutant, and GDP is per capita income. μ_i is the individual specific intercept, θ_t is the time specific effect. α, β and γ are three parameters of the Weibull and Gamma functions. u_{it} and v_{it} are both assumed to be normal disturbance term, i.e. $u_{it} \sim iidN(0,\sigma_u^2)$ and $v_{it} \sim iidN(0,\sigma_v^2)$.

Different from conventional linear and log-linear models, the classical ordinary least square (OLS) estimator can not be used when estimating the parameters for model (5) and model (6). Therefore, we turn to estimate nonlinear models with the nonlinear least square (NLS) estimator presented next.

3 Empirical Investigation

To better describe the relationship between per capita emission and per capita GDP, we use the NLS estimator to estimate the nonlinear models in panels with the Weibull and Gamma specifications. Table 1 reports the estimation results. It is shown that three parameters in both nonlinear models are all significant at 5% level of significance for three pollutants, except that the parameter β in one model with the Gamma specification for solid wastes is insignificant. The adjusted R^2 statistics are all larger than 0.85, indicating that these nonlinear models have high goodness-of-fits, and the performance of model fitting with the Weibull specification is very close to that with the Gamma specification. These results suggest that nonlinear panel data models with the Weibull and Gamma specifications have good interpretability, robust estimation and high model fitting precision.

In addition, Table 1 also reports the turning points of the EKC relationship between per capita emission of various pollutants and per capita GDP. All the nonlinear models have the resulting turning points. The turning points for waste water, solid wastes and waste gas are 26 945 yuan, 43 168 yuan and 40 927 yuan, respectively, calculated using the Weibull specification. And the turning points are in turn 25 605 yuan, 61 325 yuan and 57 139 yuan with the Gamma specification. From the magnitude of the turning points, it is relatively low for waste water, while relatively high for solid wastes and waste gas. From different functional forms, the turning points of solid wastes and waste gas with the Weibull specification are lower than that with the Gamma specification.

Table 1 Estimation results with the Weibull and Gamma specificatio

Parameter	Waste water		Solid wastes		Waste gas	
	Weibull	Gamma	Weibull	Gamma	Weibull	Gamma
α	2.101**	3.136**	1.393**	1.388**	1.923**	2.053**
	(24.27)	(9.289)	(15.13)	(14.97)	(20.27)	(17.60)
β	37998**	13699**	104548**	155211+	59136**	53915**
	(21.65)	(6.129)	(2.761)	(1.658)	(8.160)	(4.027)
γ	-991.00*	-3651.7**	1035.4**	1036.6**	551.6**	392.3**
	(-2.002)	(-2.690)	(20.09)	(19.68)	(5.649)	(2.829)
Adjusted R^2	0.8639	0.8637	0.8705	0.8702	0.8985	0.8983
Turning point	26 945	25 605	43 168	61 325	40 927	57 139

Note: Figures in parentheses are t statistics for regression parameters. "**", "*" and "+" denote that the estimator of a parameter is significant at 1%, 5% and 10% level of significance, respectively. The turning points are calculated from expression (5) and (6).

Table 2 reports the results of paired non-nested J-test between the log-linear model and the model with the Weibull specification or the Gamma specification, and between the Weibull specification and the Gamma specification. Notice that log-linear models of waste water, solid wastes and waste gas are specified as cubic, quadratic and quadratic, respectively, in term of previous results. The first two tests for the null of the log-linear model against either the Weibull specification or the Gamma specification indicate that the null are all rejected for three pollutants. On the contrary, the middle two tests show that the null of the Weibull specification or the Gamma specification can not be rejected for all three pollutants against the alternative of the log-linear model. It is confirmed that both the Weibull and Gamma specifications should outperform the widely used log-linear model. The last two tests are carried out in between the Weibull and Gamma specifications. For waste water, the null of the Weibull specification can not be rejected, but the null of the Gamma specification can be rejected, implying that the Weibull specification for describing the EKC relationship outperforms the Gamma specification. Nevertheless for solid wastes and waste gas, both the null of the nonlinear specifications can not be rejected, suggesting that either the Weibull specification or the Gamma specification may be sufficient.

Table 2 Results of paired non-nested J-tests

Hypothesis test	Waste water	Solid wastes	Waste gas
H0: Weibull, H1: log-linear	0.3563 (0.3609)	-2.690 (0.9963)	0.1393 (0.4446)
H0: Gamma, H1: log-linear	-1.777 (0.9619)	-2.981 (0.9985)	-1.223 (0.8890)
H0: Weibull, H1: Gamma	0.6623 (0.2541)	-2.445 (0.9926)	0.2440 (0.4037)
H0: Gamma, H1: Weibull	1.093 (0.1376)	6.023 (0.0000)	0.9696 (0.1664)

4. Discussions and Conclusions

It is well known that China has been experiencing the course of sustained and rapid industrialization starting at the beginning of 1980s, when the countrywide economic system reform headed from the central planning system reform towards market mechanism. Since then, per capita GDP has been kept growing at close to 10 percent per year, which is obvious to all. Rapid economic growth brings people a large welfare, while at the same time serious environmental deterioration comes into being. Environmental pollution has made it impossible to enjoy the benefit entirely from economic growth. Although positive measures have been made and some effects were acquired, it is still a problem confronted to realize the coordinative relationship between economic growth and environmental restoration. It is therefore very indispensable how to accurately judge and evaluate the current relationship between economic growth and environmental pollution.

This paper attempts to examine the relationship between economic growth and environmental pollution in China, and contrast the results of conventional linear methods with nonlinear methods. On the basis of the analysis in the above sections, we come to the following conclusions. First, an explicit evaluation is obtained as a whole for linear methods and nonlinear methods, i.e. the latter outperforms the former in describing the income-emission relationship. Detailedly, the Weibull and Gamma specifications are superior to the log-linear model, and the linear model is the most inferior one. Second, the turning point calculated with nonlinear methods is more credible than that computed with linear methods. In numerous cases with linear methods, there is not a closed-form solution, and even the turning point can be too low or too high. For instance, the turning point computed with linear model for waste water is 13029 yuan, much lower than that computed with nonlinear methods. Another example is that the turning point is excessively high calculated with log-linear model for waste gas, about 10 times that calculated with the Weibull or Gamma specification. Third, no matter with linear methods or nonlinear methods, the results suggest that with the rise of per capita GDP, per capita emission of waste water firstly increases and then decreases, having an existing turning point, while per capita solid wastes generated and per capita waste gas emission take on the monotonously increasing relationships, having very high turning points.

In conclusion, this paper provides new evidence in support of the EKC relationship between economic growth and environmental pollution in China, adopting and combining linear methods and nonlinear methods. Nevertheless, as is said by Stern (2004), EKC is an essentially empirical phenomenon, but most of the EKC literature is statistically weak. It is therefore hoped that some more powerful statistical tests and econometric tools ought to be considered for the EKC investigation.

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