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EKC Analysis of Three Industrial Wastes of Five Provinces in Northwest China

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Abstract. Environmental pollution control has been one of the hot spots in academia, and industrial waste is the main source of environmental pollution. The environmental Kutznitz curve can well measure the relationship between industrial wastes and economic growth. The paper fits the EKC model of industrial wastes data from 1995 to 2016 in five provinces of Northwest China, verifies the existence of short-term EKC, and points out that the five northwest provinces should grasp the opportunity of supply-side reform, optimize the industrial structure, and reduce the negative impact on the resources and environment while increasing the gross domestic product.

1. Introduction

Since the reform and opening up, Chinese GDP has achieved an annual high growth of more than 10%, the five northwestern provinces have also achieved rapid growth under the impetus of the national economic tide. However, we also have to admit that the environmental pressure in our country that is becoming more and more serious, especially the severe haze weather which appears many times in recent years, Environmental governance has gradually become an important topic of concern. Since the American scholar Panayotou put forward the environmental Kuznets curve in 1993, as one of the main models to describe the relationship between economic growth and environmental pollution, EKC has been concerned by scholars at home and abroad. The paper will select the data of the three industrial wastes from 1995 to 2016 in five northwest provinces to verify the inverted U-type hypothesis

2. Literature Review

In 1955, Kuznets curve was proposed to study income distribution by Simon Kutznitz, Nobel Prize-winning economist. In 1991, Grossman-Krueger first studied urban air quality data from GEMS, the results showed that the emission of SO2 and soot was in accordance with the inverted U curve. In 1992, according to the data provided by the World Bank, Shafik fitted the environmental indexes in three forms: linear logarithm, logarithmic square and logarithmic cubic. In 1993, Panayotou skillfully applied the inverted U-shape curve between income inequality and per capita income level defined by Kuznets, which is first applied to the relationship between environmental quality and per capita income, and it is called the environmental Kuznets curve. He believed that the environmental quality first deteriorated with the growth of the level of per capita income in the early stage of economic development, when the economic development reached a certain stage, the level of per capita income also rose to a certain height, and then it would improve with the level of per capita income. That is, there is the inverse U curve relationship between environmental quality and per capita income.

The literature on the relationship between pollution and economy in the underdeveloped areas of western China is less than that in the developed regions. Zhu Lin, Zhang Xiaomeng selected 17 years of environmental pollution data from 1986 to 2002 in western China, and found that the present situation of industrial effluent, industrial exhaust and so2 does not accord with the inverted U shape of the traditional Kuznets curve. Zhu Lin research showed that the three-waste per unit of GDP in the western region is higher than the eastern region. Yu Hong, Yang Kai and other scholars found that the discharge of industrial effluent has a significant decreasing trend to the increase of GDP per capita in Yunnan, Guizhou, Gansu, Qinghai, Tibet, and Inner Mongolia, the discharge of industrial effluent from Shaanxi, Ningxia and Guangxi increased with the increase of per capita GDP. Wang Yufang, Qi Yongan used economic growth and CO_2 emissions data from seven ethnic minority provinces in western China from 1995 to 2007, and it was concluded that the reduction of CO_2 emissions in Inner Mongolia could promote economic growth, and the emission of CO_2 pollutants could promote economic growth in Ningxia, Qinghai, Xinjiang, Guangxi, Yunnan and Guizhou. Hu Guoliang and Zhu Xiao believed that there was a significant causal relationship between economic growth and emissions of certain pollutants in Xinjiang but the lag of this relationship is different, and the impact of economic growth on the environment is greater than the impact of environmental pollution on economic growth. In the form of mathematical model, Bai Qirui empirically tested the emission of SO_2, and found that in the three regions of east, west and west of China, SO_2 emission per capita income elasticity was the largest in the western region, and the difference between the western and eastern regions was too big at present, which was not conducive to the improvement of environmental quality. Li Fei, Zhuang Yu constructed a model of GDP pollution emissions per capita based on the environmental quality and economic data of five provinces in Northwest China from 1995 to 2009, the coordinated development between economic growth and environmental pollution in 5 provinces of Northwest China was studied. The results showed that the environmental curve of 5 provinces in Northwest China did not accord with the characteristics of EKC. The discharge curve of industrial effluent was the superposition of U type and inverted U type, the discharge curve of industrial exhaust was increasing monotonously, and the curve of industrial solid waste was the rising stage of inverted U type curve.

3. Selection of data and indicators

The data selected in the paper are mainly derived from official data such as China Statistical Yearbook, China Environment Statistics Yearbook and the Statistical Yearbook of the Western provinces and Environmental Bulletin. Considering the availability and uniformity of the data, the data from 1995 to 2016 are selected in the paper. The main indicators selected are the discharge of industrial effluent (IEF), Industrial exhaust (IEX) and industrial solid waste (ISWN), per capita gross domestic product (AGDPN).

4. EKC Analysis of Three Industrial Wastes

4.1. Establishment of EKC model for industrial wastes

The environmental Kutznitz curve describes the relationship between income and environmental quality. There are generally quadratic, cubic, logarithmic quadratic and logarithmic cubic forms. In the paper, we select the logarithmic cubic form, logarithmic quadratic form and logarithmic cubic form to estimate, and judge the concrete form of the environmental Kuznietz curve in the five northwest provinces by the following three forms.

$$LNEPi=\beta0+\beta1\ LNAGDPi+\mu i$$

$$LNEPi=\beta0+\beta1\ LNAGDPi+\beta2\ (AGDPi)^2+\mu i$$

$$LNEPi=\beta0+\beta1\ LNAGDPi+\beta2\ (AGDPi)^2+\beta2\ (AGDPi)^3+\mu i$$

In the above formula, LNEP is the logarithm of environmental pollution index， which refers to the emissions of industrial wastes. LNAGDP is a logarithmic per capita GDP, μ is considered to affect environmental degradation of other random factors.

4.2. Test of stability

The data of time series variable actually is non-stationary, in order to avoid spurious regression, need to convert data, make it become stable sequence. ADF is a test of the existence of unit roots in time series. If the sequence has unit root, then the unit root can be eliminated by difference method, and the stationary sequence can be obtained. Table 1 presents the test results of the ADF unit root test for four groups of data, such as the logarithm of industrial waste emissions and the logarithm of per capita gross domestic product, and the corresponding first-order differential data.

Table 1. Unit Root Test of Industrial Wastes and GDP per capita

Difference order	**provinces**	**constants**	**LNIEF**		**LNIEX**		**LNISW**		**LNAGDP**	
			ADF	P	ADF	P	ADF	P	ADF	**P**
original value	Shaanxi	I	-1.9357	0.3042	-0.6395	0.8136	2.0698	0.999	-0.4631	**0.8564**
		II	0.4494	0.9945	-1.7891	0.6309	0.4175	0.9948	-2.0506	**0.5016**
		N	0.2219	0.7274	3.1575	0.9969	-2.1291	0.0584	15.5392	**0.9999**
	Gansu	I	-2.0053	0.2796	1.2207	0.9937	0.6939	0.9829	-0.6328	**0.8153**
		II	-1.6721	0.6796	-2.4747	0.3307	-3.0283	0.1894	-3.3804	**0.1284**
		N	-0.0167	0.6506	2.3064	0.9864	-1.4992	0.0631	8.4741	**0.9999**
	Qinghai	I	-2.3589	0.1761	-1.3157	0.5724	-1.8846	0.3235	-0.6189	**0.8189**
		II	-1.9526	0.5491	-1.2706	0.8238	-2.0059	0.5221	-3.3574	**0.1313**
		N	1.3476	0.9409	3.8177	0.9989	-1.0655	0.2371	9.4855	**0.9999**
	Ningxia	I	-2.3008	0.1905	-1.3059	0.5768	-0.9291	0.7278	0.1235	**0.9472**
		II	-3.0742	0.1794	-2.8669	0.2274	-1.9969	0.5257	-2.6627	**0.2715**
		N	0.3694	0.7687	1.0719	0.9102	-1.1306	0.2152	7.0558	**0.9999**
	Xinjiang	I	0.4339	0.9688	1.2099	0.9943	-1.8467	0.3382	0.0533	**0.9364**
		II	-3.7161	0.0796	-0.3748	0.9649	-3.1265	0.1608	-2.5456	**0.3099**
		N	4.2843	0.9993	6.4019	0.9999	-0.8205	0.3292	4.0276	**0.9989**
First order Difference	Shaanxi	I	-2.4053	0.1679	-2.0416	0.2668	-0.513	0.6879	-2.4647	**0.1557**
		II	-3.5021	0.044	-1.5522	0.7226	-1.8653	0.3465	-3.9436	**0.021**
		N	-2.6457	0.0653	-3.2709	0.0317	-3.3043	0.0411	-0.8987	**0.2967**
	Gansu	I	3.049	0.0718	-3.2948	0.0517	-2.5998	0.1352	-3.7416	**0.0334**
		II	-2.0932	0.4667	-3.9113	0.0717	-2.3613	0.3661	-3.1678	**0.1753**
		N	-3.2739	0.0051	-2.2563	0.0313	-2.6837	0.0464	-0.9911	**0.2604**
	Qinghai	I	-3.4419	0.0426	-3.6371	0.0331	-2.7877	0.1019	-3.7416	**0.0334**
		II	-4.2993	0.048	-3.4933	0.1134	-2.6065	0.2914	-3.1678	**0.1753**

		N	-2.9418	0.009	-0.5756	0.4326	-2.741	0.0129	-0.9911	**0.2604**
	Ningxia	I	-3.2977	0.0515	-3.2664	0.0591	-3.7744	0.0277	-3.4656	**0.0414**
		II	-7.3581	0.0029	-3.3638	0.1426	-2.939	0.2242	-3.126	**0.1696**
		N	-3.2686	0.0051	-3.1747	0.006	-3.5864	0.003	-0.3066	**0.5381**
	Xinjiang	I	-3.3806	0.0514	-1.8516	0.3343	-3.7979	0.0268	-3.8729	**0.0243**
		II	-2.902	0.2303	-2.0634	0.4869	-3.8038	0.0805	-3.9815	**0.0787**
		N	**-1.9843**	**0.0481**	**-3.2863**	**0.0056**	**-3.9561**	**0.0017**	**-0.2773**	**0.5493**

Note: I, II and N respectively denote that there are constant terms, constant term and trend term, no constant in the regression equation of unit root test.

It can be seen from the above table that the four groups of data in the five provinces of Northwest China are not significant at the level of 5%, indicating that the five provinces of Northwest China are LNIEF, LNIEX, and LNISW. The fictitious hypothesis that LNAGDP has unit root can not be rejected, but after the first order difference, the unsteady hypothesis is rejected at the significant level of 5%. After the first order difference, the LNIEFU LNIEX LNISWN GDP is stable.

4.3. Co-integration test

Co-integration refers to a linear combination of multiple non-stationary economic variables. The linear combination is stable. In the process of co-integration analysis, the most commonly used method is EG two-step method. In the paper, the form of linear regression is as follows.

$LNEPi=\alpha+\beta\ LNAGDPi+\mu i$

Estimating the above linear regression model, its residual sequence is obtained and its stability is tested. The co-integration regression DW test is used in the paper. The results are shown in Table 2.

Table 2. Co-integration Test of Industrial Wastes and GDP per capita

provinces	**DW**		
	LNFS	LNFQ	**LNFW**
Shaanxi	0.6808	0.71	**0.6712**
Gansu	0.97	0.8012	**1.0619**
Qinghai	1.3015	1.6383	**1.9945**
Ningxia	1.1377	1.137	**1.0233**
Xinjiang	**2.0275**	**1.1336**	**0.9861**

Table 2 shows that all tests show that the residual sequence is stable, and then there is co-integration relationship between LNIEF、LNIEX、LNISW、LNAGDP.

4.4. Model estimation

In order to estimate the EKC, the author estimates three possible relationships between the discharge of industrial effluent, the discharge of industrial exhaust, the discharge of industrial solid waste and GDP per capita in the five provinces of Northwest China. The second and third terms are added in order to set the model. In the time selection, the first half of the data is estimated, then the second part of the data is estimated, and finally all the data are estimated. The result of the final estimation and the phase state of the curve are shown in Table 3.

Table 3. Estimation Results and Curve Shape of EKC Model for Industrial Wastes

provinces	explanatory variable	LNIEF			LNIEX			LNISW		
		95-05	06-16	95-16	95-05	06-16	95-16	95-05	06-16	95-16
Shaanxi	intercept	80.8	-28.6	272.5	73.8	600.5	121.5	-188.0	-113.0	24.4
	linear	-16.5	8.0	-85.9	-16.2	-184.9	-37.3	46.6	27.3	-1.3
	Quadratic	0.9	-0.4	9.34	1	19.1	4.0	-2.8	-1.47	
	Cubic			-0.3		-0.6	-0.1			
	F	7.3	24.9	43.9	57.4	243.8	305.5	5.5	34.6	85.2
	R^2	0.71	0.87	0.90	0.95	0.99	0.98	0.64	0.90	0.84
	Curve Shape	U	reversal U		U	reversal N		reversal U		\
Gansu	intercept	18.0	52.7	45.5	57.0	64.2	23.0	6.9	30.4	-31.5
	linear	-0.9	-9.2	-7.7	-12.5	-12.8	-4.1	-0.3	-2.0	11.25
	Quadratic		0.5	0.4	0.8	0.7	0.3			-0.7
	Cubic									
	F	46.5	16.3	79.6	11.4	48.2	132.5	1.2	169.4	149.4
	R^2	0.86	0.82	0.91	0.79	0.93	0.94	0.15	0.95	0.95
	Curve Shape	\	U	U	U	U	U	×	\	reversal U
Qinghai	intercept	3928	-58.4	407.4	-4.7	-32.4	-3.7	1571	22.4	21.79
	linear	-1380	13.4	-129.2	1.3	7.2	1.2	-365.4	-1.3	-1.3
	Quadratic	161.9	-0.7	13.9		-0.3		21.2		
	Cubic	6.3		-0.5						
	F	14.6	13.7	21.9	41.3	338.4	902.9	12.5	5.6	12.5
	R^2	0.89	0.79	0.82	0.85	0.98	0.98	0.80	0.40	0.43
	Curve Shape	reversal N	reversal U	reversal N	/	reversal U	/	U	×	\
Ningxia	intercept	2432	-74.7	234.4	-2.07	-3.2	-3.0	-153	20.7	18.0
	linear	-853	17.1	-76.4	1.1	1.2	1.2	36.4	-1.1	-0.8
	Quadratic	100	-0.9	8.6				-2.1		
	Cubic	-3.9		-0.31						
	F	39.0	8.5	32.4	6.4	44.1	151.9	0.2	12.7	14.9
	R^2	0.95	0.71	0.87	0.47	0.84	0.90	0.05	0.61	0.48
	Curve Shape	reversal N	reversal U	reversal N	×	/	/	×	\	\
xinjiang	intercept	11.3	5.3	208.4	91.3	-911	19.00	-3044	19.40	-32.16
	linear	-0.2	0.5	-61.6	-19.7	282.3	-3.4	1035	-0.6	9.8

	Quadratic			6.3	1.2	-29.0	0.2	-117		-0.5
	Cubic			-0.2		1		4.4		
	F	2.6	414.8	62.1	54.6	442.9	620.3	0.1	5.7	2.3
	R^2	0.27	0.98	0.93	0.94	0.99	0.98	0.04	0.41	0.23
	Curve Shape	×	/	reversal N	U	N	U	×	×	×

Note: "x" means no functional relation, "/" means positive correlation, "\" means negative correlation, and other forms are not repeated.

5. Conclusions

Judging from the whole development trend of human society or the development trend of a country, the environmental quality experienced by human beings should be inverted U-shaped, which can be regarded as a long-term environmental Kuznets curve.However, different environmental policy, foreign trade openness and other factors are different in each country and region, the relationship between environmental pressure and economic growth in the short term shows three shapes similar to those in the third part of this paper, which can be regarded as the short-term environmental Kuznets curve.Generally speaking, the Kutznitz curve in the early stage of industrialization approximates to the linear increasing pattern, but in the period of industrialization it presents the inverted U type, and the late stage of industrialization is approximately in the form of linear decline.

Because many of the data are selected in different time periods, the fitted EKC shapes are different, which is not inconsistent with the assumption of the environmental Kuznets curve, there are only looking at the short-term environmental Kuznets curve. In general, the growth rate of GDP in Gansu and Ningxia has exceeded the capacity of the environment because of the influence of high pollution and energy consumption on the industrial structure of heavy industry and the depletion of resources. If we do not change the direction of development and blindly develop pollution-intensive industries in order to increase the growth rate of GDP, it will inevitably lead to a further rise in environmental pressure. Other provinces in the western provinces can appropriately increase the growth rate of gross domestic product, but we should also pay attention to control pollution emissions, seize opportunities for supply side reform, optimize industrial structure, and increase the gross output while reducing the negative impact on resources and environment.

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