The Influence of Land Intensive Use and Urbanization to Air Pollution: Evidence from China

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Abstract: Urbanization has a significant impact on environmental pollution, but the relationship between urbanization and environmental pollution is complex. This paper separately discusses the population urbanization and land urbanization relationship of air pollution, and the impact of urbanization level and land intensive utilization on air pollution are used for empirical analysis. The panel data of 35 provincial capitals and sub provincial cities in China are selected from 2003 to 2015, and index system is constructed to evaluate the level of urbanization, land urbanization and land intensive use. After testing the Heteroscedasticity between panels, Autocorrelation within groups and contemporaneous correlation across panels of the panel data, an econometric model is established and a comprehensive feasible generalized least squares (FGLS) method is chosen to estimate the consistent and valid results which show the effects of urbanization, land urbanization and land intensive utilization on air pollution. This paper puts forward the related questions and policy recommendations.

1. Literature review

The study of the relationship between environmental pollution and urbanization mainly includes two aspects: first, referring to the methods of social economic development and environmental pollution, the environmental Kuznets (EKC) curve is tested by using the level of urbanization and environmental pollution. D. F. Huang (2011) used the panel data of 29 regions in China from 1999 to 2008 to verify the inverted N-type relationship between industrial wastewater and urbanization, the N-type relationship between industrial sulfur dioxide and urbanization, and the U-type relationship between industrial dust and urbanization [3]. Second, experts have studied the relationship and industrial structural transformation, political incentives [4], local government finance Decentralization [5] and other factors in the process of urbanization. Also, there are few empirical studies on the joint effect of urbanization and land intensive utilization on environmental pollution. The current research methods are generally based on the establishment of econometric models, using cross-sectional data especially panel data, to analyze the relationship between environmental pollution and urbanization. At present studies begin using panel data which bring new problems. Stern (1996) proposed that the econometric model used to validate the environmental Kuznets curve is easy to produce Heteroscedasticity problems [6]. This paper uses city-level data to study the relationship between comprehensive urbanization and air pollution.

2. Theoretical analysis

The core feature of urbanization is that the population is gathering from countryside to urban. On one hand, due to urban population increasing and lifestyle changing, the environmental requirements of urban residents on the living space and environment quality are increasing. On the other hand, the gathering urban population can enrich human resource in the city, and the division of labors can

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concentrate technical expertise on fighting against air pollution, resulting in the improvement of air quality. Expanding of city construction land shows the trend of spatial expansion, which is characterized by the intensive urban built-up area and the continuous expansion of urban construction areas. The urbanization process of China and the vicious urbanization competition between cities lead to the disorderly expansion of cities. Dust in construction, vehicle exhaust and solid waste could result in air quality deterioration. Finally, the current research ignores that the transformation of urban spatial structure and the rational economic layout of cities are mutually reinforcing processes. To gain advantage in the competition, the local government generally chooses the attitude of positive competition, negative cooperation and the "race to the bottom", which may lead to the negative impact on the environment and unreasonable layout.

3. Models and data source

3.1 Benchmark model

Referring to the previous research results, the relationship between urban environmental pollution and urbanization is established as the benchmark model.

$$En_{it} = \alpha_i + \beta \sum X_{it} + \delta urban_{it} / \delta land_{it} + a_i + u_{it} \quad (1)$$

In the benchmark model, $\mathrm{En_{it}}$ represents the i city environmental pollution at t year, α_i is constant, $\mathrm{X_{it}}$ are control variables; $\mathrm{urban_{it}}$ represents the i city urbanization level in the city at t year, $\mathrm{land_{it}}$ stands for the i city land intensive use level in the at t year. $\mathrm{a_i}$ is unobserved effects in each city. $\mathrm{u_{it}}$ is random error term. Alpha, beta and delta are the parameters to be estimated for each variable.

3.2 Data source

China's provincial capitals and sub provincial cities are selected as the research objects[1].Because of the lack of data in Lhasa, this article deleted the Lhasa city. Therefore, the results of this paper do not involve Lhasa. This paper obtains data from "Chinese Statistical Yearbook", "China Population and Employment Statistics Yearbook", "China Urban Construction Statistics Yearbook", "China City Construction Statistical Yearbook" and the China Economics Information Network Database from 2003 to 2015.

The control variables include the proportion of the second industry added value, the per capita real GDP and the quadratic per capita real GDP, respectively, named as $rindus2, rpgdp, rpgdp2$. Per capita real GDP, removes the factor of price change of "current price GDP" in Chinese City Statistical Yearbook, for the base year 2000 constant price GDP per capita.

The urban air pollution index selected in this paper is the total amount of industrial sulfur dioxide emissions and sulfur dioxide emissions per square kilometer, marked them as $SO2$ and $indusso2$, respectively. The core independent variable in this paper are urbanization rates and land intensive use. Since the main research object is urban environmental quality in this paper, the urbanization is investigated from population urbanization and land urbanization two ways.

3.3 Index system and Index weights

The measurements of urbanization generally include population proportion method, coefficient adjustment method, rural urbanization index method, urban land use index method and modern urbanization index method [7]. However, in current studies, the proportion of urban population is generally used to measure the urbanization rate. It is necessary to establish the index system to calculate the urbanization level from many angles [8]. Therefore, this paper chooses to establish the index system to comprehensively assess the population and land urbanization.

From the perspective of population urbanization, this paper takes the convenience of data acquisition into account, compares it with other studies [9-11], and prepares to reflect population urbanization from two aspects of urban population and urban employment. So this paper chooses the urban total population, non-agricultural population proportion, the proportion of urban population, the proportion of urban employment population, and non-agricultural employment proportion to establish an index system to evaluate population urbanization. The score of population urbanization recorded as $popindex$.

In the perspective of land urbanization [9-11], this paper, considering the urban land use diversity, chooses population density, road area per capita, city construction land proportion and built-up area of the city four indicators to establish an index system, marked as $landindex$. The population density index represents the bearing capacity of the city to population, road area per capita index reflects the situation of traffic within city, construction land proportion and built-up area of the city accounted for the expansion of land.

The level of intensive land use in the city is measured from the land economic index and land investment [10-11]. This index system includes: land economic density index, city economic expansion coefficient, city construction land expansion index, electricity consumption per square kilometer, city public transportation passenger volume and green area accounts for the built-up area. The land economic density is expressed by the ratio of the urban economic output and the urban area. City economic expansion coefficient means that the ratio of city construction land growth rate and the ratio of the second and third industrial output growth rate; the ratio of city construction land growth rate and the ratio of urban population growth rate stands for construction land expansion index.The determination of index weight has a very important impact on the effectiveness of an index system. Therefore, this paper uses entropy method to determine the weight of each indicator in the index system. Specific weights are shown in table 1. Descriptive statistics of each variable are shown in table 2. In this paper, total 35 large and medium cities in China are selected from 2003 to 2015, so there are 455 observations.

Tab.1 Evaluation index system and the weights of population urbanization, land urbanization and urban land intensive level.

Indicators	Index	Weights
population urbanization	urban total population	0.470
	non-agricultural population proportion	0.158
	urban population proportion	0.187
	urban employment population proportion	0.182
	non-agricultural employment proportion	0.003
land urbanization	population density	0.241
	road area per capita	0.122
	city construction land proportion	0.377
	built-up area of the city	0.260
land intensive use	economic density index	0.260
	city economic expansion coefficient	0.014
	construction land expansion index	0.302
	Electricity consumption Per square kilometer	0.003
	city public transportation passenger volume	0.227
	Green area accounts for the built-up area	0.194

Tab.2 Descriptive statistics of variables.

	Variables	Obs	Mean	Std. Dev.	Min	Max
Dependent variables	$so2$	455	50.38017	78.87616	0.0399132	647.7653
	$indusso2$	455	104344.7	101600.7	92	712000
Independent variables	$popindex$	455	0.0021978	0.0011552	0.0006865	0.0068947
	$landindex$	455	0.0021978	0.0016424	0.0001775	0.0150864
	$landuse$	455	0.0021978	0.0016383	0.0003569	0.0108612
control variables	$rindus2$	455	43.28442	8.432197	19.25	61.59
	$rpgdp$	455	58039.04	44509.93	8924.697	296882.7
	$rpgdp2$	455	5.35e+09	1.08e+10	7.97e+07	8.81e+10

4. Econometric models

4.1 Econometric models

$$En_{it} = \alpha_i + \beta_1 rindus2_{it} + \sum_{k=1}^{2} \beta_{k+1}\, rpgdp_{it}^{k} + \delta popindex_{it} + a_i + u_{it} \quad (2)$$

$$En_{it} = \alpha_i + \beta_1 rindus2_{it} + \sum_{k=1}^{2} \beta_{k+1}\, rpgdp_{it}^{k} + \delta landindex_{it} + a_i + u_{it} \quad (3)$$

$$En_{it} = \alpha_i + \beta_1 rindus2_{it} + \sum_{k=1}^{2} \beta_{k+1}\, rpgdp_{it}^{\square} + \delta landuse_{it} + a_i + u_{it} \quad (4)$$

The econometric model of environmental pollution and the population of the city for the equation (2), environmental pollution and city land of econometric model for equation (3), the environmental pollution and the level of land intensive use of econometric models for equation (4), En_{it} on behalf of the i City Environmental Quality at time t, α_i is a constant. $rindus2_{it}$ stands for the i City in the second industry outcome proportion of GDP at the time t. $pergdp_{it}$ on behalf of the city at the time of t per capita GDP, $popindex_{it}$, $landindex_{it}$, $landuse_{it}$ on behalf of the population urbanization, land urbanization and land intensive use, respectively. a_i is the unobserved effects of each city. u_{it} is random error term. Alpha, beta and delta are the parameters to be estimated for each variable.

4.2 Heteroscedasticity between panels Test

The variance of random error of $city_i$ is $\sigma_i^2 \equiv Var(u_{it})$. If $\sigma_i^2 \neq \sigma_j^2 (i \neq j)$, the random error term has Heteroscedasticity between panels.. In this paper, Wald test is built to test the Heteroscedasticity, which provided by Greene (2000). The result is shown in Table 3.

Tab.3 The results of Heteroscedasticity test between panels.

Model	Heteroscedasticity Test	
	Chi2 Value	P Value
Specification 3	20568.50	0.0000***
Specification 4	63081.54	0.0000***
Specification 5	64410.37	0.0000***

[a] NOTE: *** p<0.01, ** p<0.05, * p<0.1

4.3 Autocorrelation within panels Test

If $Cov(u_{it}, u_{is}) \neq 0 (t \neq s, \forall i)$, then the random error tern has Autocorrelation within panels. This paper uses Wald test to test the Autocorrelation(Wooldrige,2002). The results are shown in Table 4.

Tab.4 The results of Autocorrelation test within panels.

Model	Autocorrelation Test	
	F Value	P Value
Specification 3	31.248	0.0000***
Specification 4	32.697	0.0000***
Specification 5	32.815	0.0000***

[a.] NOTE: *** p<0.01, ** p<0.05, * p<0.1

4.4 Contemporaneous Correlation between panels Test

$Cov(u_{it}, u_{jt}) \neq 0 (i \neq j, \forall t)$ stands for the random error term has Contemporaneous Correlation which we follows Pesaran (2004) and Frees (1995, 2004) to test it. The result shown in Table 5.

Tab.5 The results of Contemporaneous Correlation test between panels.

Model	Contemporaneous Correlation Test			
	Pesaran Test		Frees Test	
	T Value	P Values	1% Critical Value	Test Value
Specification 3	3.897	0.0001***	0.3901	7.950
Specification 4	2.560	0.0105**		9.652
Specification 5	2.643	0.0082***		9.588

[a] NOTE: *** p<0.01, ** p<0.05, * p<0.1

5. Empirical results

Throughout the above test, we could know that the panel datas have the Heteroscedasticity between panels, Autocorrelation within groups and contemporaneous correlation across panels. If the residual correlation caused by some unobserved common factors, then the common OLS, WLS, fixed and random effects may obtain consistent estimates of parameters, but the estimation is invalid, which would lead to a wrong conclusion. So we assumes the specific form of heteroscedasticity, contemporaneous correlation and autocorrelation, and then uses a feasible generalized least squares (FGLS) method to estimate the results. The results of the feasible generalized least squares method are shown in Table 6.

In Model1, the coefficient of per capita real GDP is significantly positive, and its quadratic term is significantly negative. That is to say, it is the same as the environmental Kuznets curve predicted, the relationship between sulfur dioxide emissions per square kilometer and economic development is inverted U on the basis of controlling the urbanization level of the population. As the economy develops, air pollution level rises first and then declines. The coefficient of population urbanization is negative, which shows that the agglomeration effect of population will reduce sulfur dioxide emissions.

In Model2, the coefficient of per capita real GDP is negative, and its quadratic term is not significant. The relationship between sulfur dioxide emissions per square kilometer and the level of social and economic development is a linear relationship. As economic develops,air pollution declines. The coefficient of land urbanization is positive, which means the urban spatial expansion will significantly increase the sulfur dioxide emissions per square kilometer.

In Model3, the coefficient of per capita real GDP is significantly negative, and its quadratic term is zero.That means the relationship between air pollution and economic development is linear, and air pollution is decreasing with the development of economy. The coefficient of land intensive use is significantly positive, indicating that urban land intensive utilization will increase the amount of sulfur dioxide emissions. The possible explanation is that vicious urbanization competition of local governments on environmental regulation, which results in land intensive use of sulfur dioxide emissions and the level of simultaneously rises in the city.

In this paper, weighting the population urbanization and land urbanization as 1:1, we get $urban$ variable to judge the overall urbanization level. In Model4, the coefficient of per capita GDP was not significant, while its quadratic item is significantly positive. Controlling the overall level of urbanization, the curve between social and economic development and air pollution is the inverted U type, and its symmetry axis is Y axis. In the first quadrant, with the increase of the social economic development, the air pollution declined. The coefficients of $urban$ were positive. It shows that the process of urbanization will make air pollution more serious. The coefficient of $landuse$ is significantly positive, showing that the level of intensive land use will increase pollution, but comparing with the Model3, the absolute value of its coefficient has decreased significantly. The result indicates that, on the basis of controlling the urbanization level, the level of land intensive use works to reduce air pollution.

Tab.6 FGLS results.

	(1)	(2)	(3)	(4)
so2	model1	model2	model3	model4
popindex	-17,645***			
	(1,461)			
landindex		33,516***		
		(1,236)		
landuse			28,764***	13,882***
			(1,453)	(1,492)
landuse2				
landuse3				
urban				33,350***
				(2,464)
rindus2	-0.758***	-0.171	-0.514***	-0.594***
	(0.133)	(0.148)	(0.186)	(0.215)
rpgdp	0.000235**	-0.000347**	-0.000543***	-0.000296
	(9.41e-05)	(0.000156)	(0.000158)	(0.000181)
rpgdp2	-7.44e-10**	-7.91e-10	-1.31e-09	-1.89e-09***
	(3.39e-10)	(9.43e-10)	(8.60e-10)	(6.24e-10)
Constant	101.0***	6.974	39.29***	-5.289
	(10.68)	(7.018)	(10.05)	(16.15)
Observations	455	455	455	455
Number of id	35	35	35	35

[a.] NOTE: *** p<0.01, ** p<0.05, * p<0.1

6. Conclusions

The empirical results show that ①with the development of social economy, air pollution will gradually decline, as EKC predicted. When control the level of urbanization and the level of intensive utilization of land at the same time, the development of social economy and the relationship between air pollution become an inverted U type, and the axis of symmetry is the Y axis. ②in the model1-model5, the $rindus2$ coefficient is negative, indicating second industry value adding will reduce the environmental pollution. This is contrary to the general conclusion. The possible reason is that China's industrialization has entered post industrialization stage with low pollution and high added value, which illustrates that the transformation of China's industry was relatively successful in the past decade. ③after controlling intensive land use , the coefficient of overall urbanization is also positive, meaning that the urbanization process may lead to the deterioration of air quality.

Population urbanization has a major positive influence on the city's air quality, but the land intensive use and spatial expansion of the city has increased the city environmental problems. Therefore, in the process of urbanization, it is necessary to stop the disorder expansion of the urban space and change the present urbanization, so as to attract the population as much as possible while expanding the space. The size of the space of the city should be restricted, especially China domestic large and medium-sized city, it should also actively explore the optimal size of city space, eliminate the disorder of city land expansion, and improve the level of intensive use of land. Second, the optimal amount of population should be determined by the city's environment, resources and energy capacity. Finally, local government should actively implement the policy of "national new urbanization plan (2014 - 2020)" proposed "strictly control the city population policy", and prevent the "great urban diseases".

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