

The effects of urbanization on the environment pollution in China (2002-2012)

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Abstract. This paper provides an analytical framework to evaluate whether urbanization could lead to environment pollution or not. This study uses STIRPAT model and recently developed panel regression techniques that allow for heterogeneous slope coefficients and cross-section dependence to model the impact that urbanization has on SO₂ emissions for a panel of 28 provinces in China from 2002 to 2012. The estimated contemporaneous coefficients on the urbanization variables are reverse U-shape. The corresponding policy suggestion is that the government should accelerate the urbanization to transfer the economy from a manufacturing based economy to a service based economy.

1 Introduction

Rapid urbanization in China is having increasing impact on the environment of the growing urban population. More than 450 million of China's 1.3 billion population are now living in urban area where over 70 percent of China's gross domestic product(GDP) are generated, and where the environmental impacts of concentrated human activities are felt the most. Air pollution is one of the most visible environment problems in China's urban life. Especially, the ambient concentrations of sulfate, a fine particulate most damaging to human health, can lead to unsustainable development in China. If urbanization has a significant impact on sulfurs emission(SO₂) then this will have implications for sustainable development and urbanization policies.

If urbanization is found to have a positive and statistically significant impact on SO₂ emissions then this can affect forecasting models and urbanization policy. Forecasting models of SO₂ emissions that fail to take into account the impact of urbanization on SO₂ emissions will under forecast sulfur dioxide emissions. Energy and environmental policies that omit the impact of urbanization on SO₂ emissions will likely lead to inaccurate outcomes making sustainable development objectives. If urbanization is found to have a negative and statistically significant impact on SO₂ emissions then this will make sustainable development objectives easier to achieve. And if urbanization is found to have positive and statistically significant impact on SO₂ emissions and then have negative and statistically significant impact on SO₂ emissions, then we will make urbanization develop faster to span the period of negative influence stage.

This paper makes several important contributions to the literature. Firstly, the relationship between

urbanization and SO₂ emissions has been studied by a number of authors, but most of this research uses a static model applied to a panel data set. A panel data set is believed to be better than cross-sectional data or time series data by including both time and cross-section dimension. However, static models cannot capture dynamic relationships. This paper uses a static and dynamic framework to model the impact of urbanization on SO₂ emissions in order to compare the results obtained by the two different models. Secondly, previous studies have mostly assumed that the impact of SO₂ emissions is homogeneous across time-series. This is a very strong assumption to make and one that is unlikely to hold across a large grouping of times. In this paper panel regression models are estimated using recent developed techniques that allow for panel unit root test. If panel data exhibits time-series dependence, estimating models with homogeneous slope coefficients may yield estimated coefficients that are biased(Andrew, 2005). In order to solve these problems, this paper use unit root tests and panel cointegration analysis.

2 A brief review of literature

According to Poumanyvong and Kaneko (2010), the existing literature points to three theories (ecological modernization, urban environmental transition and compact city theories) that are useful for explaining how urbanization can impact the natural environment.

The theory of ecological modernization details how urbanization is a process of social transformation that is an important indicator of modernization. As societies move from low to middle stages of development, environmental problems may increase because in these stages of development, economic growth takes priority

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over environmental sustainability. As societies continue to evolve to higher stages of development, environmental damages become more important and societies seek ways to make their societies more environmentally sustainable. The damaging impact of economic growth on the environment may be reduced by technological innovation, urbanization, and a shift from a manufacturing based economy to a service based economy (Crenshaw and Jenkins, 1996; Gouldson and Murphy, 1997; Mol and Spaargaren, 2000). The compact city theory believes that higher urban density can enhance the use of public infrastructure and lead to lower environmental damages (Burton, 2000; Capello and Camagni, 2000).

3 Data and Model

3.1 model

Following other authors, a Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model is used to investigate the relationship between urbanization and SO2 emissions (eg. Liddle and Lung, 2010; Martinez-Zarzoso and Maruotti, 2011; Poumanyong and Kaneko, 2010). The STIRPAT model is based on the Influence, Population, Affluence, and Technology (IPAT) model developed by Ehrlich and Holdren (1971). The IPAT model relates environmental impact to population, affluence (consumption per capita), and technology.

$$I = P \times A \times T \tag{1}$$

The IPAT model has been criticized as 1) being primarily a mathematical equation or an accounting identity which is not suitable for hypothesis testing, and 2) assuming a rigid proportionality between the variables. In response, Dietz and Rosa (1997) proposed a stochastic version of IPAT.

$$I_{it} = a_{it} P_{it}^b A_{it}^c T_{it}^d e_{it} \tag{2}$$

In Eq.(2), counties are denoted by the subscript *i* (*i*=1,2,...,N) and the subscript *t* (*t*=1,2,...,T) denotes the time period. Country specific effects are included through *a_{it}* and *e_{it}* represents the random error term. And we use this model to analysis the urbanization on the environment of each provinces in China. Taking natural logarithms of Eq.(2) provides a convenient linear specification for panel estimation.

$$\ln(I_{it}) = b \ln(P_{it}) + c \ln(A_{it}) + d \ln(T_{it}) + v_i + \varepsilon_{it} \tag{3}$$

Country specify effects are included through *v_i* and *ε_{it}* represents the random error term. The STIRPAT model can easily accommodate additional explanatory variables and in this paper, model(3) is augmented with urbanization(*U*). The augmented model is

$$\ln(I_{it}) = b \ln(P_{it}) + c \ln(A_{it}) + d \ln(T_{it}) + f \ln(U_{it}) + v_i + \varepsilon_{it} \tag{4}$$

When it comes to estimating Eq.(4), a distinction can be made between models with homogeneous slope coefficients and models with heterogeneous slope coefficients. If the assumption of homogeneous slope coefficients is made then these models can be estimated

using standard panel regression techniques like pooled OLS (POLS) and various fixed effects (FE), random effects (RE), or GMM specifications. Models with heterogeneous slope coefficients can be estimated using mean group (MG) estimators (eg. Pesaran and Smith, 1995; Pesaran, 1997) or variants on mean group estimators. Estimating panel models with heterogeneous slope coefficients is currently an active area of econometrics (eg. Eberhardt et. al., 2013).

3.2 Data and resources

The empirical analysis is based on a panel of 29 provinces in China over the period of 2002-2012 because China government had implemented the policy of urbanization reforming from 2002. Due to a lack of data, Tibet is not included and Chongqing is combined to Sichuan. These samples are restricted to those provinces for which the data on the urbanization level denoted as the proportion of the Chinese population living in urban areas (*y_{it}*), and the data was abstracted from China Statistical Yearbook 2003-2013(the National Statistics Bureau of China, 2003-2013). The dependent variable environment pollution index is measured by SO2 emission value (*x_{it}*), which was also from various issues of China Statistics Yearbook 2003-2013(the National Statistics Bureau of China, 2003-2013). Table 1 presents the definition of the variables and the corresponding summary statistics.

Table 1. variable definitions and descriptive statistics.

variable	definition	method	mean	min	max
u	ration of citizen to total population	y=urban _{it} /p opulation _{it}	0.48	0.24	0.89
s	the amount of so2 emission	s=Sulphur Dioxide _{it}	78.13	2.2	200.3
s ²	the square of s	s ² =s ²	8575.48	4.84	40120.09
ls	logarithmic form of s	ls=s ²	4.06	0.79	5.3
Ds	the difference of s	Ds=s _t -s _{t-1}	4.06	0.79	5.3

3.3 Unit root tests

The possible non-stationary property of the data is investigated by applying Bai and Carrion-i-Silvestre(2009) allowing for the structural breaks and cross-sectional dependence. The tests of belong to the so-called “second-generation” of panel unit root tests and have the important advantage to overcome the main limitation of previous tests. Although the tests show that we can reject the null hypothesis that there is a unit root, we can’t still confirm that every variable does not have a unit root. Table2 shows that we can find a unit root in lag(3) for SO2, but we can find a unit root for u. So we must use the lag of u to solve the non-stationary problem.

Table 2. tests of unit root.

	coefficient	t-value	t-star	P
so2				
lag(2)	-0.6531	-15.57	-11.7192	0.0000
lag(3)	-0.2389	-6.74	0.0560	0.5223
u				
lag(2)	-0.2602	-6.27	-1.5222	0.0640
lag(3)	-0.1753	-4.16	0.2029	0.5804

4 Results

Table 3 presents empirical results for static models with heterogeneous slope coefficients. The estimated coefficient on the urbanization variable is between 0.617 and statistically significant at the 5%. The column(3) in table3 shows that the relationship between urbanization and environment pollution is reverse U shape. That means the environment can damage in the process of urbanization firstly, but as population density in city increase and the public infrastructure can facilitate migrant worker. Hence, The damaging impact of economic growth on the environment reduces by urbanization, and a shift from a manufacturing based economy to a service based economy. The column(4) and column(5) in table3 report the results of the panel cointegration tests by Westerlund and Edgerton(2008), and we can get the same conclusions as original panel regression.

Heterogeneous parameter estimates from the dynamic panel model are reported in Table 4. Looking first at the contemporaneous variables, the estimated coefficient on the affluence variable is positive and statistically significant at the 1% level. The values is -0.59 indicating a negative effect. And we can also get reverse U shape adding lagged dependent variable.

Table3. the results of panel data regression(static).

	(1)	(2)	(3)	(4)	(5)
	m1	m2	m3	m4	m5
VARIABLES	so2	lso2	lso2	lso2	lso2
u	10.14	0.617**	5.713***		
	(15.16)	(0.257)	(0.928)		
u2			-		
			5.435***		
			(0.957)		
D.u				1.566	2.843**
				(0.972)	(1.297)
D2.u					-1.563*
					(0.905)
Constant	73.26***	3.763***	2.687***	4.065***	4.061**
	(11.54)	(0.210)	(0.280)	(0.162)	(0.162)
Observations	319	319	319	290	261
Number of n	29	29	29	29	29

Table4. the results of panel data regression(dynamic).

	(1)	(2)	(3)	(4)	(5)
	m1	m2	m3	m4	m5
VARIABLES	so2	lso2	lso2	lso2	lso2
u	-	-	-	2.278**	
	12.29*	0.590***	0.680**	*	
	**		*		
	(3.457)	(0.196)	(0.197)	(0.777)	
D.u			2.183**		2.835**
			*		*
			(0.817)		(1.090)
L.so2	0.970*	0.00916*	0.00924	0.00856	0.00986
	**	**	***	***	***
	(0.0100)	(0.00068)	(0.00067)	(0.0006)	(0.00075)
)	1)	4)	80)	7)
u2				-	
				2.987**	
				*	
				(0.786)	
D2.u					-1.214
					(0.761)
Constant	9.248*	3.651***	3.662**	3.073**	3.271**
	**		*	*	*
	(2.091)	(0.139)	(0.136)	(0.206)	(0.107)
Observations	290	290	290	290	261
Number of n	29	29	29	29	29

5 Concluding

This paper uses a STIRPAT model to explore the impact that urbanization has on sulfur dioxide emissions in China. It is expected that urbanization will continue rising in China and understanding how urbanization affects SO2 emissions is an important and timely topic to study. A better understanding of how urbanization affects SO2 emissions is necessary from a sustainable development perspective. For static specifications estimated and dynamic specifications estimated, we both get the same conclusion that the relationship between urbanization and SO2 emissions is reverse U-shape. The corresponding policy suggestion is that the government should accelerate the urbanization to transfer the economy from a manufacturing based economy to a service based economy.

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