The Impact of Compact Urban Management on Environmental Quality: Evidence from Chinese Cities

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Abstract. Periods of decentralization had exerted a tremendous pressure on the cities environmentsustainability. The compact city concept was seen as an approach that could end "the evil of urban sprawl". This paper uses GDP density as the index of compact city to examine the determinants of environment sustainability in China using a spatial econometric framework. The results confirm that pollution is positively affected by pollution in nearby cities. Investigations of the determinants of environment sustainability that ignore this spatial relationship are likely to be mis-specified. Considering the spatial effect, the statistical significant inverted U-shaped curves are found in the estimation of the impact of GDP density on the pollution. It illustrates that city's pollution will be decreased with the compact urban development.

Introduction

The concept of the compact city is a key urban management strategy to limit suburban sprawl and to obtain a more sustainable urban development. Urban sprawl has been shown to be highly inefficient, especially in the provision of services and infrastructure by local governments. In China, Beijing is a typical case.

There is a large literature that highlights the role of compact forms of urbanization as a basis for a more sustainable urban development (United Nations, 1993; European Commission, 2011). Many reports suggest that a compact city reduces energy, makes investments in public infrastructure more viable, reduces land usage thereby preserving agricultural land and natural areas, and is positively associated with social diversity and with cultural and economic development (Elkin et al., 1991; European Commission, 2011). However, there is also a considerable group of researchers who argue that the case of the compact city is not proven and that there is evidence which suggests that the claims of the supporters do not reflect the hard reality of economic demands, environmental sustainability and social expectations (Nabielek, 2012). The empirical example of Taiwan shows the density and the process of intensification not only positively influences economic sustainability but also negatively influence environmental and social sustainability (Lin and Yang, 2006). However, the few studies that examine the effect of externality in the analysis of determinants with a spatial econometric approach. This paper contributes to the literature is this way.

The paper is organized as follows. Section 2 examines a number of spatial econometric issues and the data source in this paper. Section 3 adopts the spatial econometric approach to test the spatially adapted model at the China municipal cities level, and section 4 concludes the paper.

Methodology and Data

Following Gert de Roo (2000), the relationship between the compact city and the environmental is for more than one reason controversial. The compact urban development will mostly likely have a negative effect on the quality of the environmental. Refer to the Environmental Kuznets Curves; we posit a relationship between the logarithm of cities' emissions per capita, the logarithm of GDP density and their squared value. The estimation equation is given by:

$$log(E)=\alpha_1+\beta_1 \, log(compact \; city)+\beta_2 \, [log(compact \; city)]^2+e \qquad (1)$$

Where E is either log of per capita waste water, SO2 or Soot emissions in cities, compact city is measured by either GDP per Km^2 municipal district. To allow for the U shaped curves, I include the log compact city and the square of the log of compact city.

It is well known that regional data cannot be regarded as independently generated because of the presence of spatial similarities among neighboring regions (Anselin et al., 1996). None growth of the country, neither economic nor environmental (sustainable) can exists without any impact of regions situated closely. Spatial econometrics recognizes that units might be correlated across space (Anselin, 1988). As indicated above, estimating a linear model with least squares in the presence of spatial correlation would yield biased estimates. The spatial lag model for compact urban development and environment sustainability is given by:

$$log(E) = \alpha_1 + \beta_1 \, log(compact \, city) + \beta_2 \, [log(compact \, city)]^2 + \rho W log(E) + \mu \qquad (2)$$

The variable gathered by the term Wlog(E) is therefore the spatial lag for the pollution. We interpret an influence of this variable on the endogenous as evidence of intercity spillovers of the pollution. The second way to incorporate spatial autocorrelation into the model is to specify a spatial

process for the disturbance term.

$$log(E) = \alpha_1 + \beta_1 log(compact \, city) + \beta_2 \, [log(compact \, city)]^2 + \mu$$

$$\mu = \lambda W \mu + \varepsilon) \qquad\qquad\qquad\qquad\qquad\qquad (3)$$

All the Dates were taken from the China City Statistical Yearbook 2010. The number of cities is 284; some cities are not chosen in this paper for the missing values.

The main dependent variables used in this paper are three pollutants: Waste Water emissions, SO2 emissions and SOOT emission. The three emissions are the main pollutions in China. As such, they clearly capture a measure of environmental quality. Based on the previous research (Burton, 2002; Matsumoto, 2012), we use Secondary and tertiary industry GDP per km^2 municipal district as the proxies of compact city. Table I presents the explanatory variables included in the model, and report the descriptive statistics. In order to avoid sharp fluctuations of the data, the paper takes the logarithm form for all the variables.

Table 1: Summary statistics

Variable	Definition	mean	Min	Max	SD
WATER	Industrial waste water discharged per ten thousands population	5.120	3.606	6.295	0.434
SO2	Industrial SO2 emission per ten thousands population	2.058	-0.677	3.276	0.490
SOOT	Industrial soot emission per ten thousands population	1.549	-0.237	2.984	0.476
GDP DENSITY	Secondary and tertiary industry GDP per Km^2, municipal district	3.386	1.393	4.762	0.620

Empirical Estimation and Results

The equation is estimated by OLS for each pollutant in turn and the results are presented in Table 2. The elasticity of emissions with respect to economic index of compact city is positive and strongly significant. This illustrate that there are a monotonic relationship between compact city and Water & SO2 emissions per capita. The models than include a second-order effect for compact city indicate that, on average, there is evidence of an inverted-U relationship between SOOT emissions and compact urban development. The turn point is 3.579; it means that form this level of compact urban development provides to decrease of SOOT emissions.

Table 2: Results of OLS model

Independent Variables	WATER	SO2	SOOT
Constant	3.433***	0.641	0.043
	(0.536)	(0.632)	(0.635)
GDP DENSITY	0.752**	0.713*	0.866**
	(0.332)	(0.391)	(0.393)
GDP DENSITY2	-0.073	-0.084	-0.121**
	(0.050)	(0.059)	(0.060)
R-squared	0.155	0.048	0.024
F-statistic	25.858***	7.138***	3.464**
Log likelihood	-141.927	-189.117	-190.326
Akaike info criterion	289.854	384.234	386.651
Moran's I	6.501***	6.164***	7.681***
LM-lag	12.473***	37.338***	50.349***
Robust LM-lag	1.830	6.352**	2.686
LM-error	39.315***	35.252***	55.268***
Robust LM-error	28.672***	4.266**	7.604***

Notes: Observations 284 regions; Robust standard errors are given in parentheses; * significant at the 10% level; **significant at the 5% level; *** significant at the 1% level.

With a deeper relation to our goal is the fact that spatial autocorrelation in the residuals is clearly discovered, as shown in the lower section of Table 3.The LM-LAG clearly reject the null of absence of spatial autocorrelation at the 1% level of significance, indicating misspecification of the model, so that some kind of externalities across regions may take place in the explanation of the regional economy. We followed Anselin's (1996) recommendation and used the Lagrange Multipliers to decide on a spatial lag or spatial error respecification. Here, the spatial lag model is the preferred respecification. When estimated by ML, the explanatory power of the regressions is substantially and significantly increased and the significant value of the Likelihood Ratio tests in spatial lag dependence point to the statistical adequacy of the estimation of the spatial models. Location and distance are important forces of spatial spillovers of air pollutions, the coefficients on the spatial lag and spatial error terms are highly significant. In SO_2 spatial lag model, the spatial lag term of $WlogSO_2$ reflects the spatial dependence inherent in the sample data, measuring the average influence on observations by their neighboring observations. In Water and SOOT spatial error model, the coefficient on the spatially correlated errors Lambda is added as an additional indicator. It has a positive effect.

Table 3: Results of spatial econometric model

Independent Variables	WATER	SO2	SOOT
Constant	2.568***	-0.417	-0.661
	(0.536)	(0.583)	(0.626)
GDP DENSITY	1.317***	0.821**	1.283***
	(0.323)	(0.359)	(0.379)
GDP DENSITY2	-0.162***	-0.104*	-0.183***
	(0.048)	(0.055)	(0.057)
ρ		0.461***	
		(0.054)	
λ	0.677***		0.664***
	(0.050)		(0.051)
R-squared	0.314	0.193	0.228
Log likelihood	-119.360	-168.734	-163.897
Akaike info criterion	244.721	345.469	344.762
Likelihood ratio test	45.134***	40.764***	52.857***

Considering the spatial effect, it is clear that the environmental impact indicator is an inverted U-shaped function between pollution and economic index of compact city. The turning point of compact city for Waste Water emission, SO_2 emission and SOOT emission is 4.065, 3.947 and 3.505 (logarithm value) respectively. It means that from these levels of compact city, the

environment degradation decrease. Many cities in China have beyond the turn point. It illustrate that the relationship between the pollution and compact urban development of these cities is on the stage of benign circulation.

Conclusion

The main purpose of this paper has been to highlight the relationship between compact urban development and environmental sustainability. Results obtained are made robust to possible spatial dependence or correlation across observations through the use of spatial econometrics tools. After having detected the presence of spatial effects in the model, the study find there are an inverted U-shaped curve of the impact of GDP density on the environmental quality. It implies the cities' environment sustainability will be improved gradually with the economic development of compact city.

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